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(54) **THERMAL PRINTER WITH REDUCED DONOR ADHESION**

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Related U.S. Application Data

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(51) **Int. Cl.**
B41J 2/335 (2006.01)

(52) **U.S. Cl.** **347/171**

(58) **Field of Classification Search** 347/171–223
See application file for complete search history.

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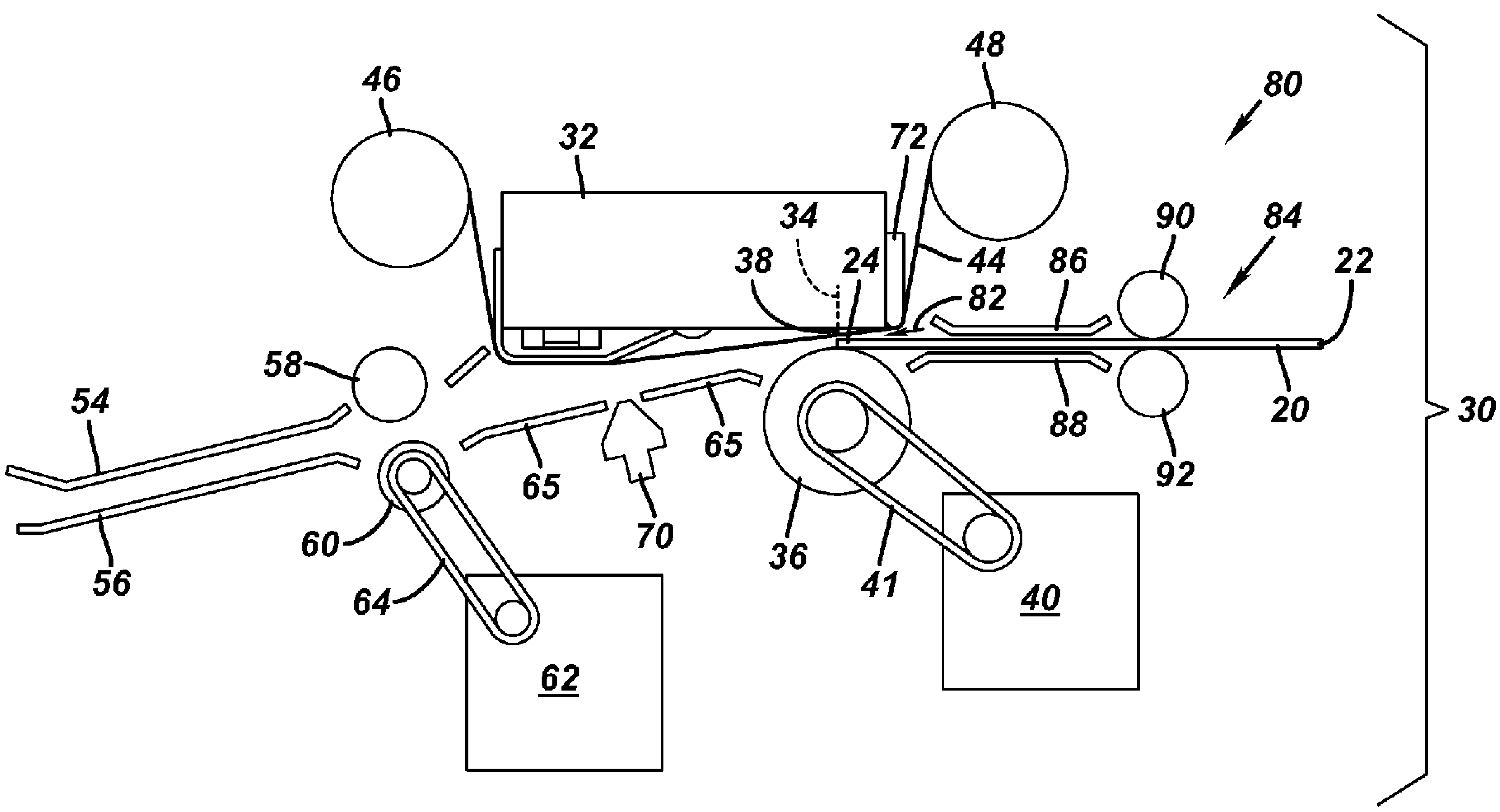
(57) **ABSTRACT**

Thermal printers and methods for operating thermal printers are provided. In one method, a sequence of thermal print head control signals is generated that is adapted to cause an array of thermal elements to cause the donor material to transfer from a donor ribbon in a manner that is modulated in accordance with image data and attenuated in accordance with an attenuation pattern. A receiver medium is urged through the printing nip while the thermal print head control signals are transmitted to the thermal print head to cause the donor material to transfer from the donor web in an image modulated pattern having a longitudinal length that is larger than a longitudinal length of the receiver medium. The attenuation pattern provides a relatively high level of attenuation at a portion of the printing wherein there is greater risk that the receiver medium will not be within the printing nip.

7 Claims, 17 Drawing Sheets



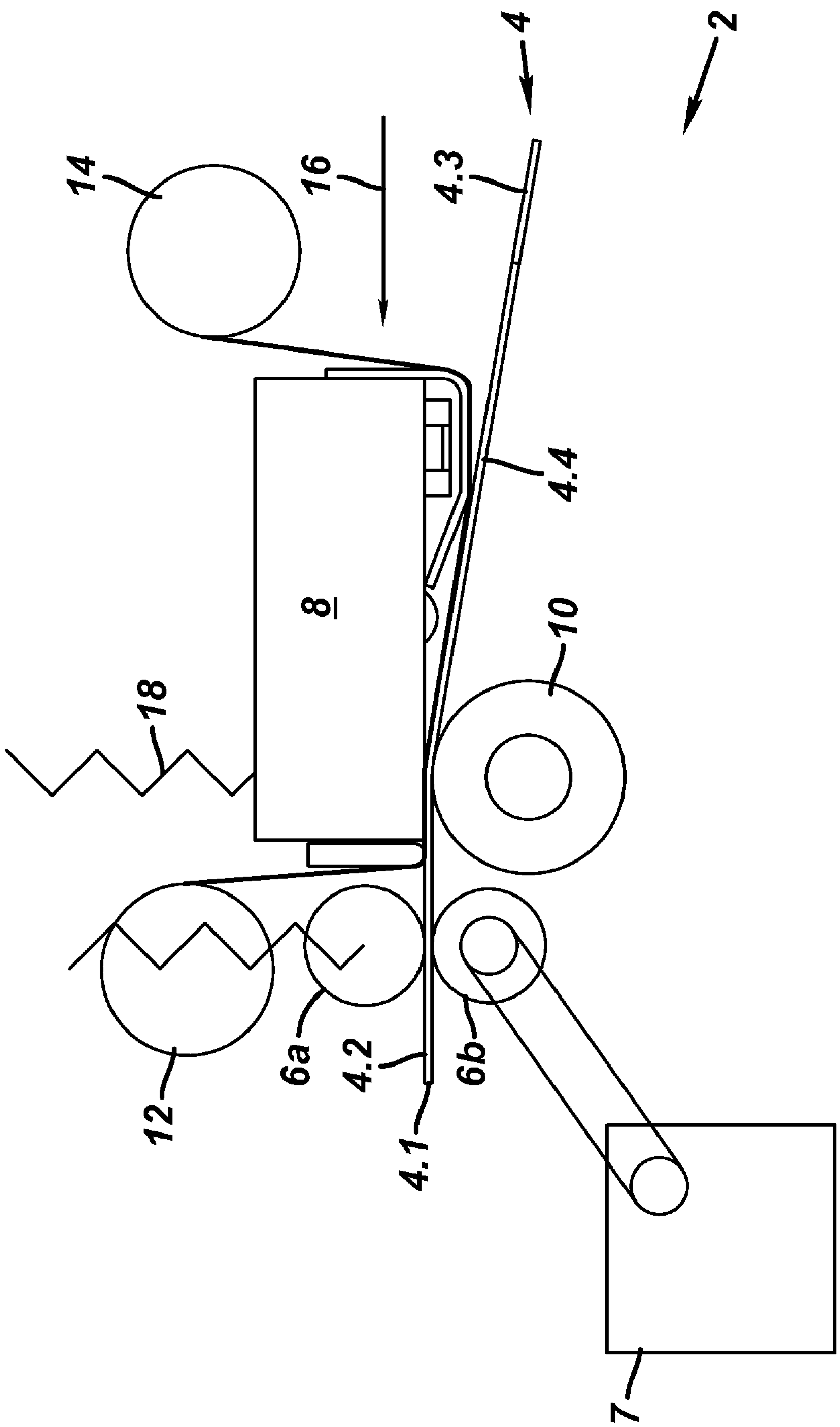
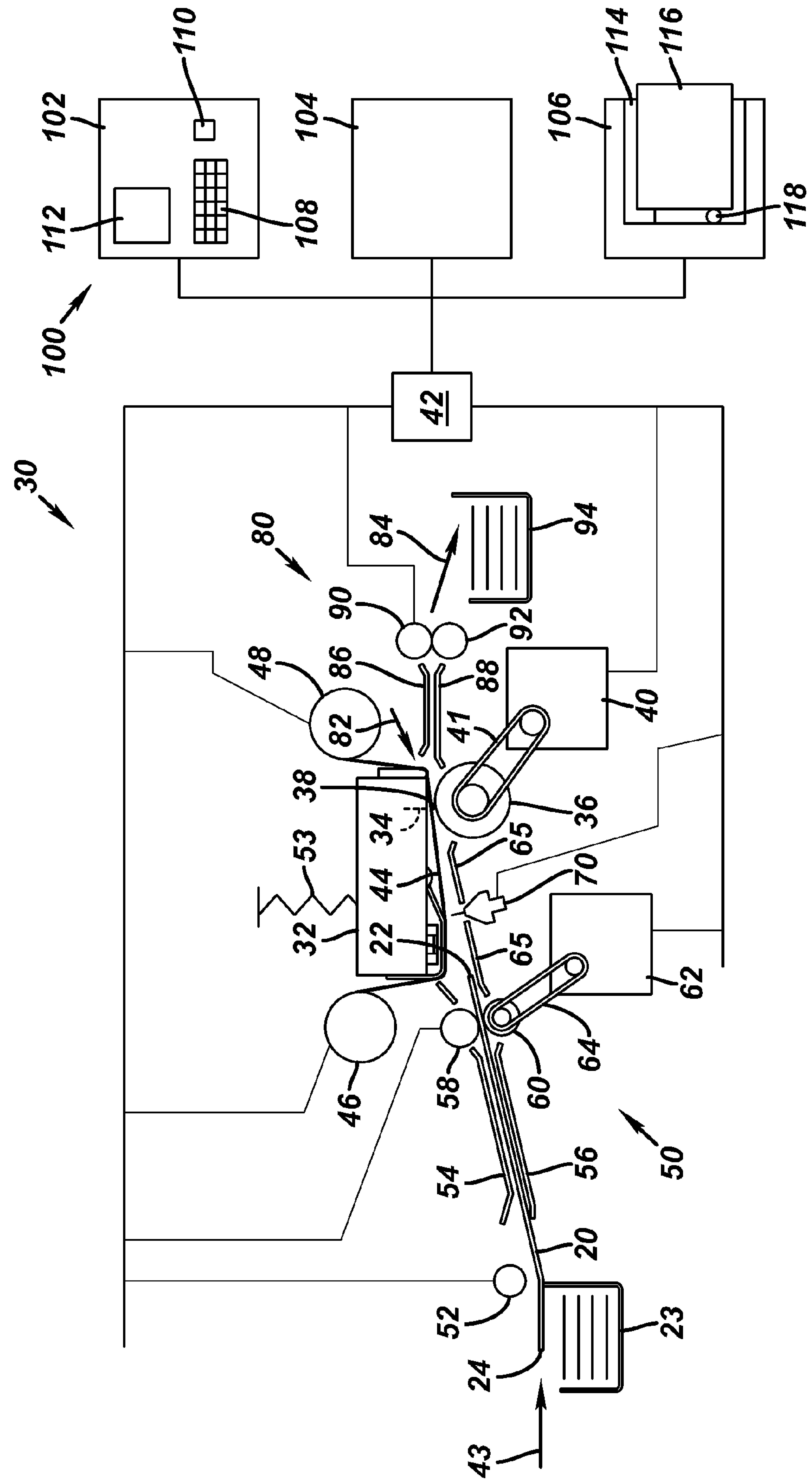


FIG. 1
PRIOR ART



100
102
104
106
108
110
112
114
116
118
30
42
80
84
94
90
92
86
88
48
82
41
40
38
36
34
65
70
53
44
32
22
62
46
58
60
64
50
54
56
20
52
23
24
43

FIG. 2

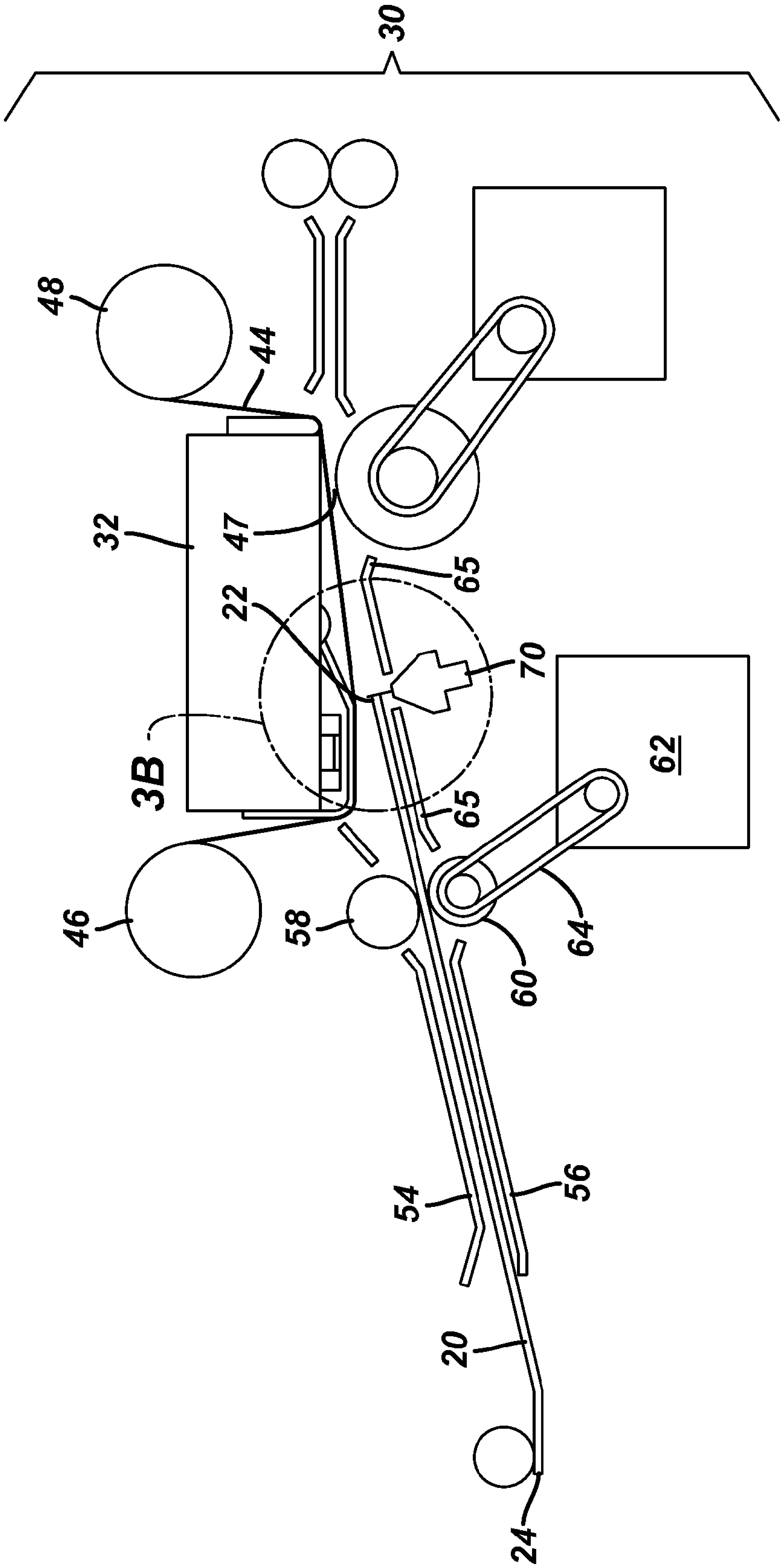


FIG. 3A

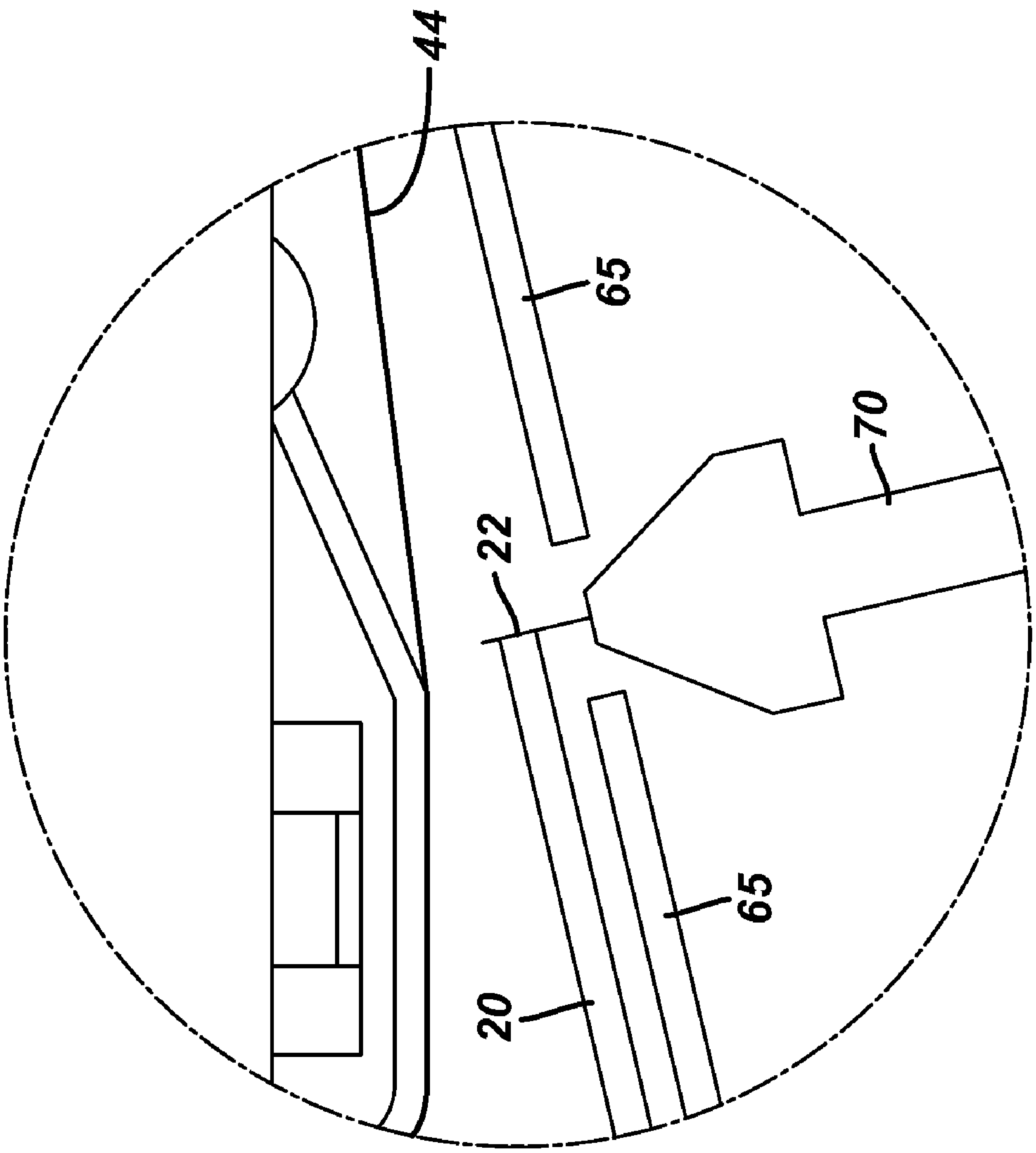


FIG. 3B

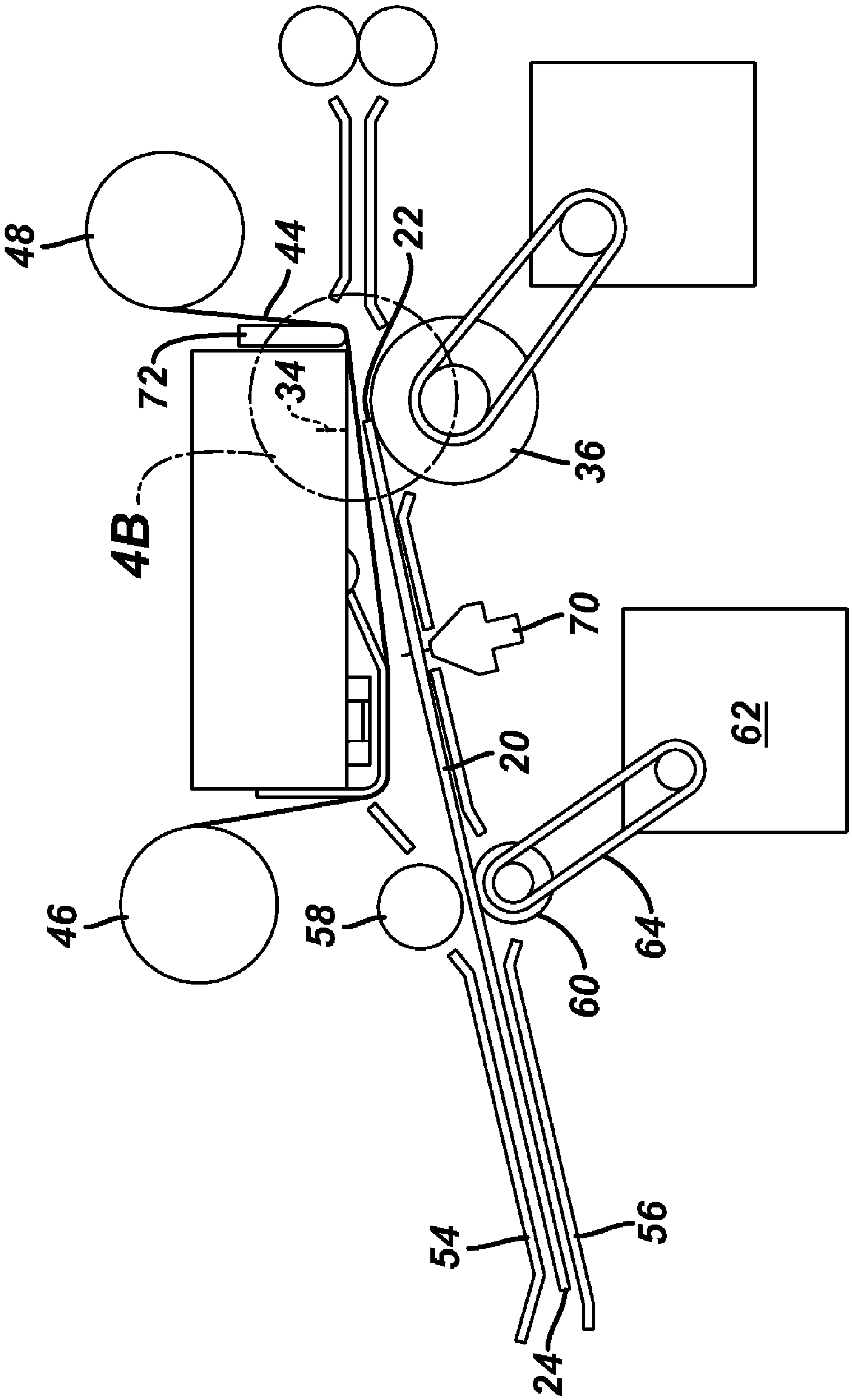


FIG. 4A

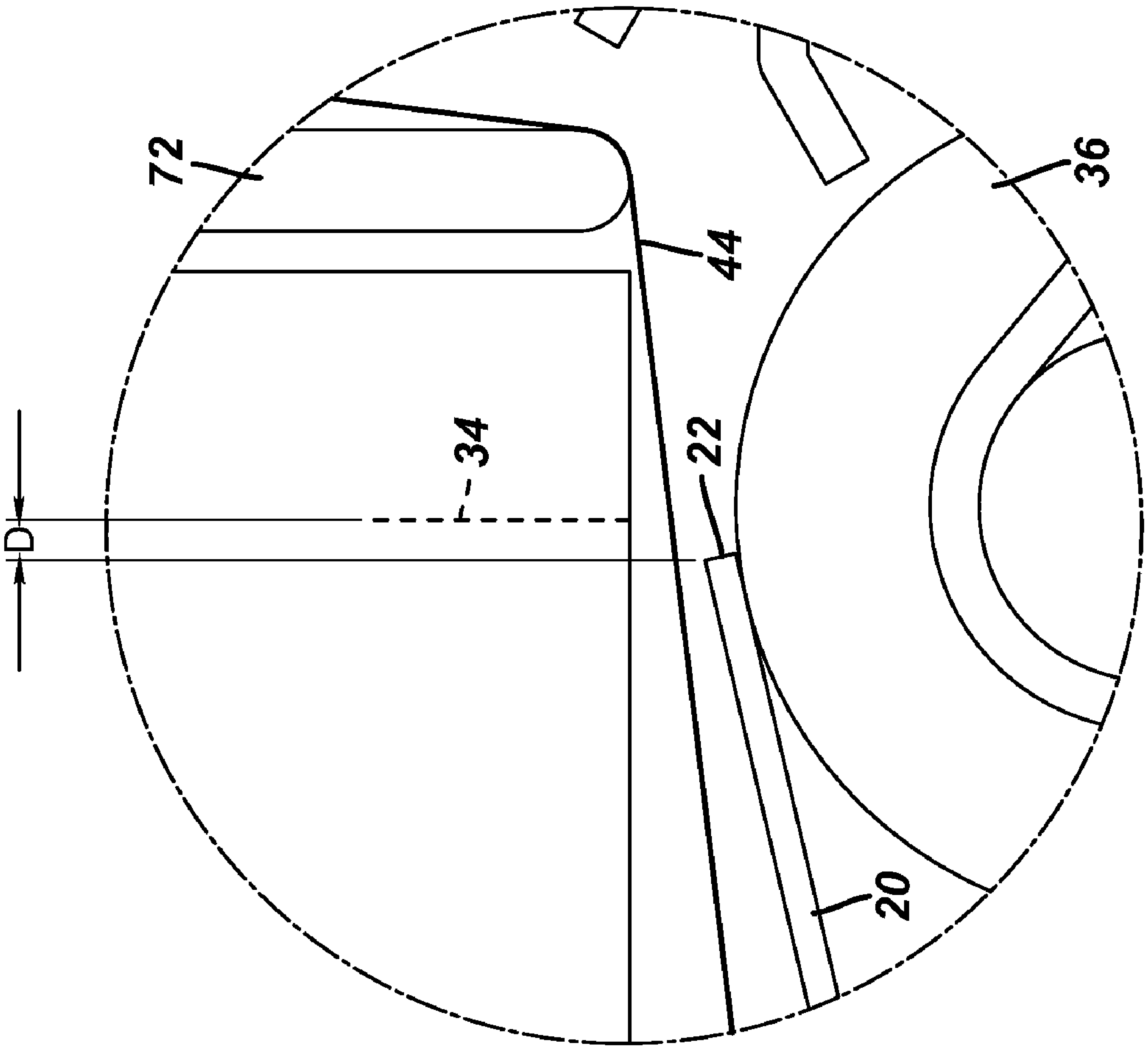


FIG. 4B

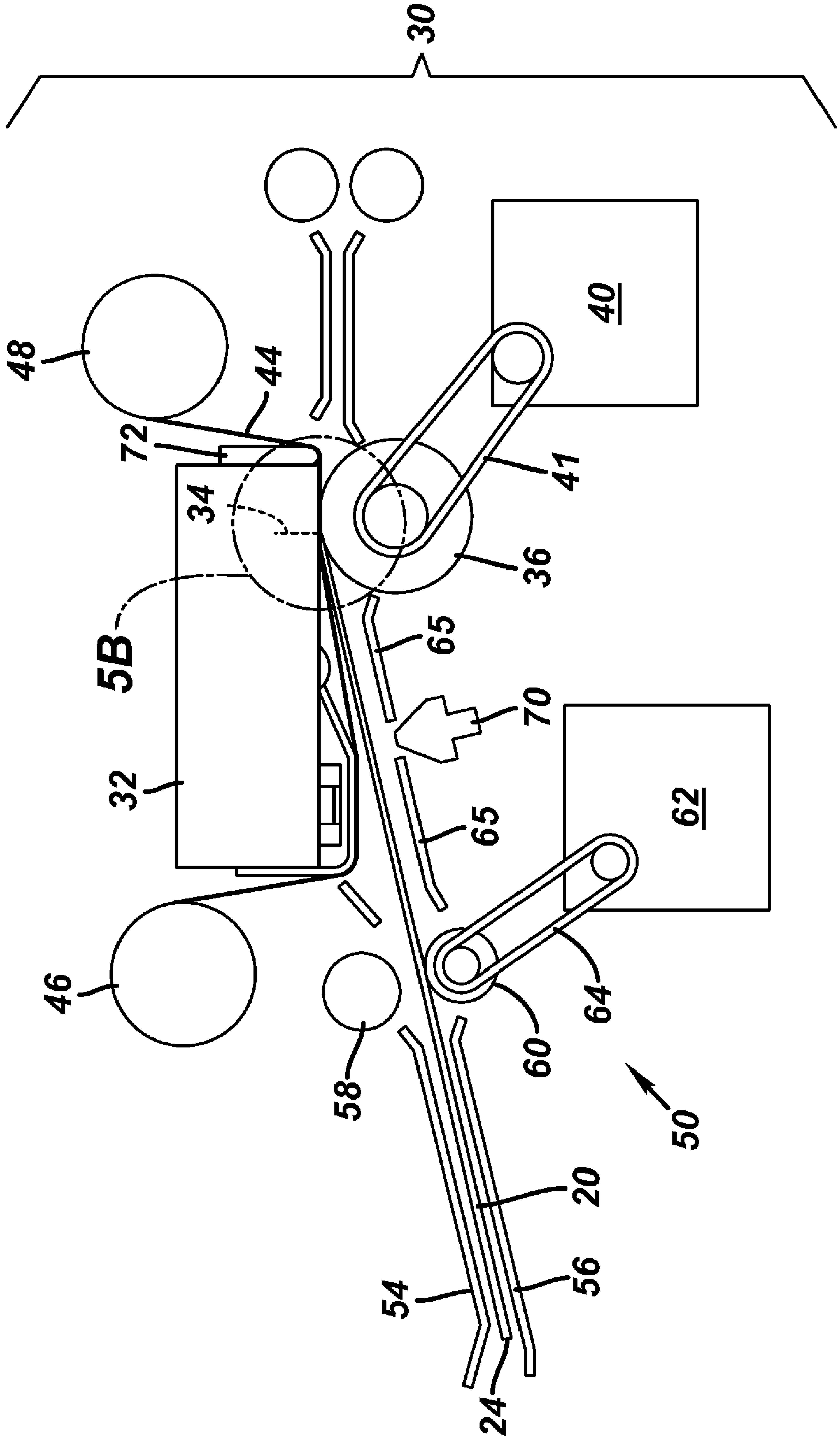


FIG. 5A

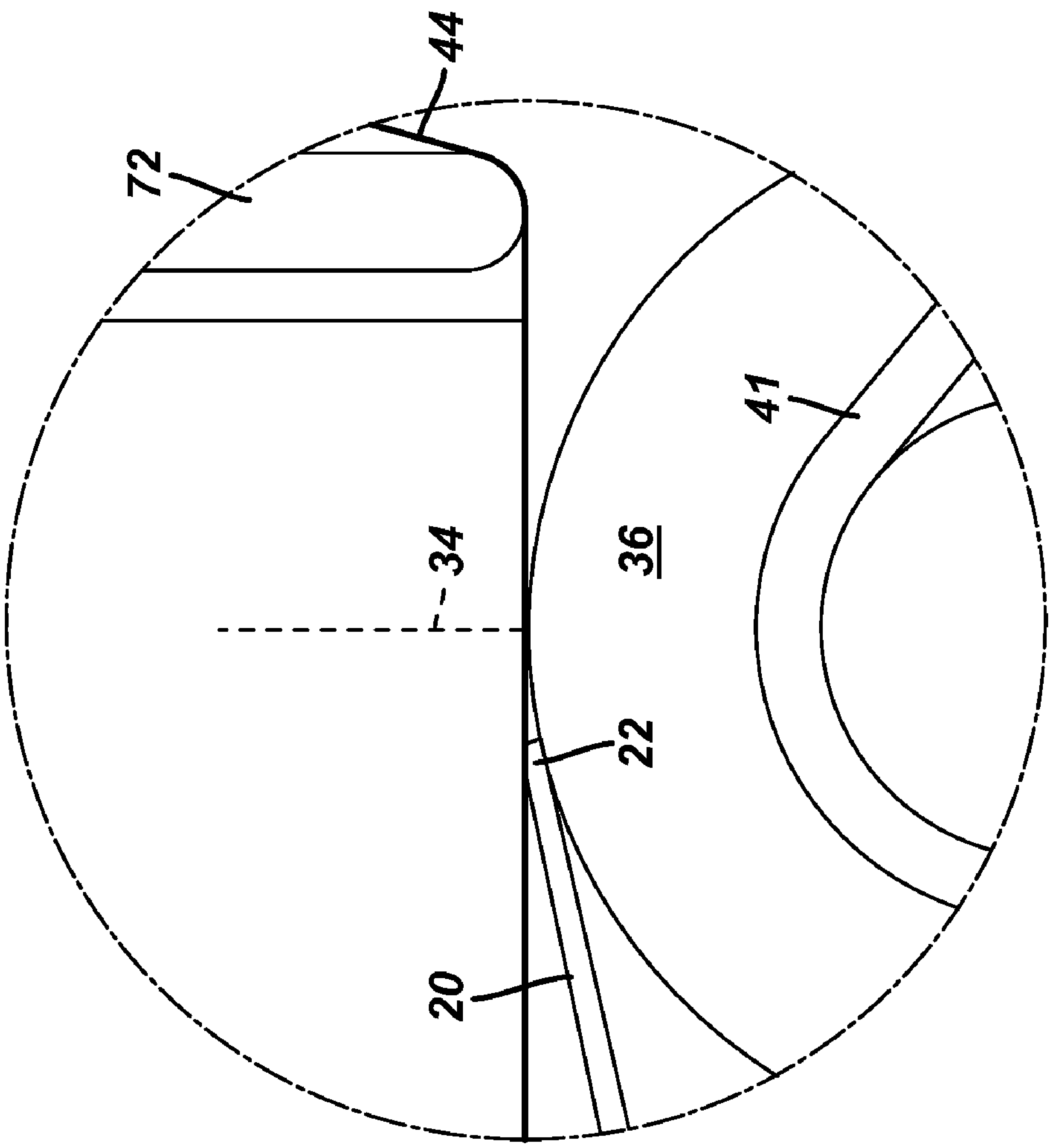


FIG. 5B

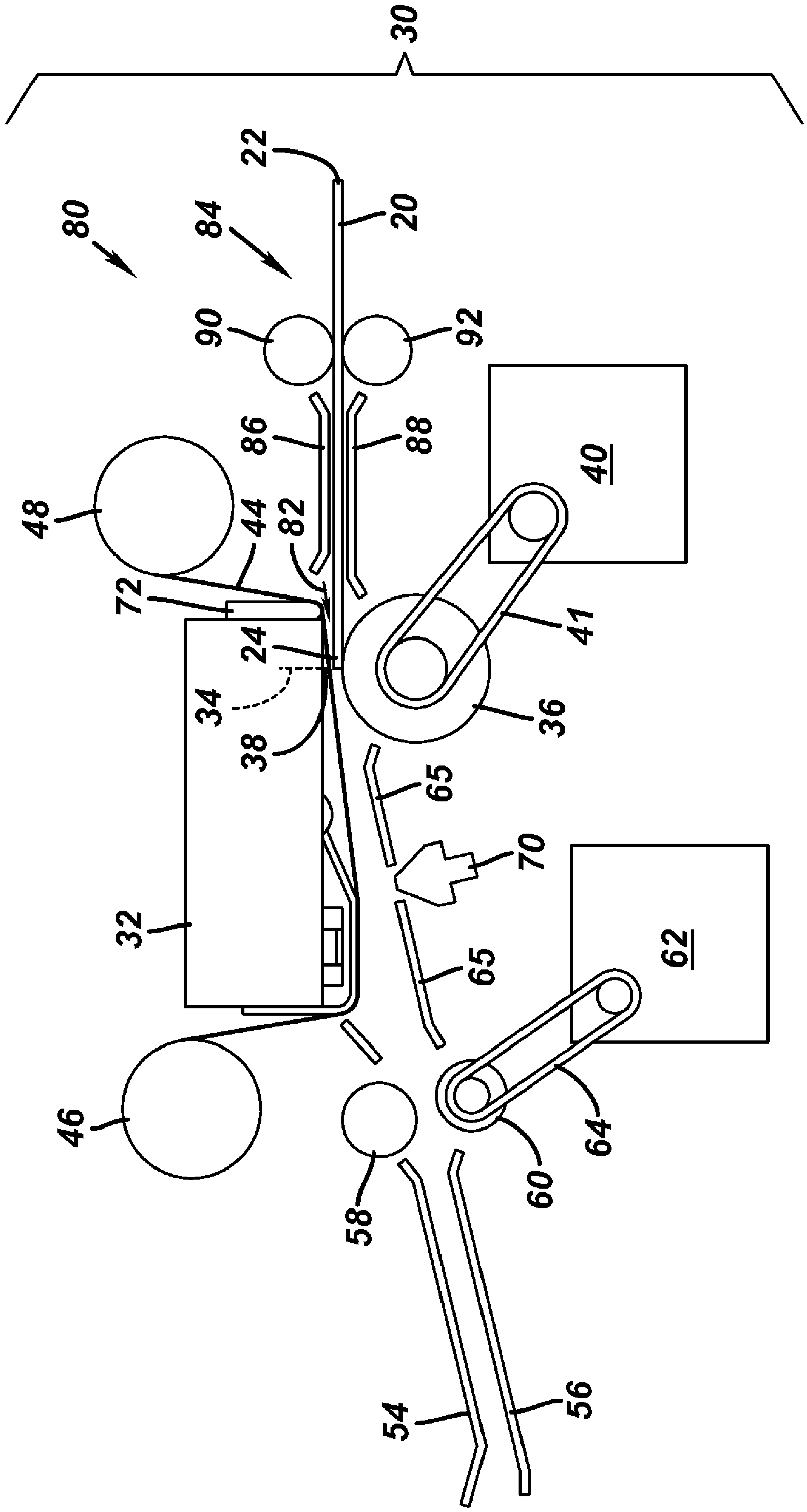

30
22
20
80
84
90
92
86
88
48
44
82
40
72
24
41
34
38
36
65
70
32
62
65
46
58
60
64
54
56

FIG. 6

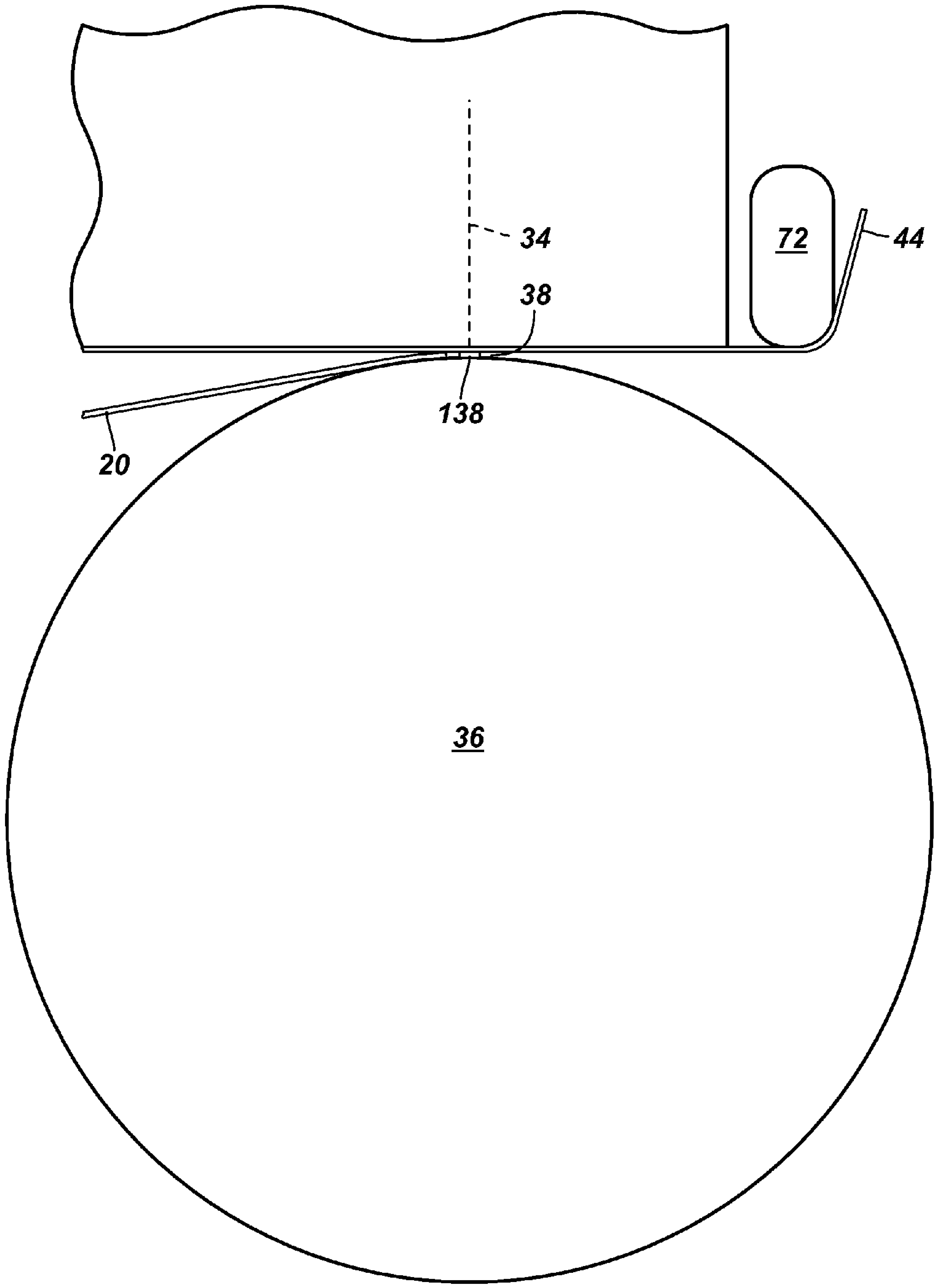


FIG. 7A

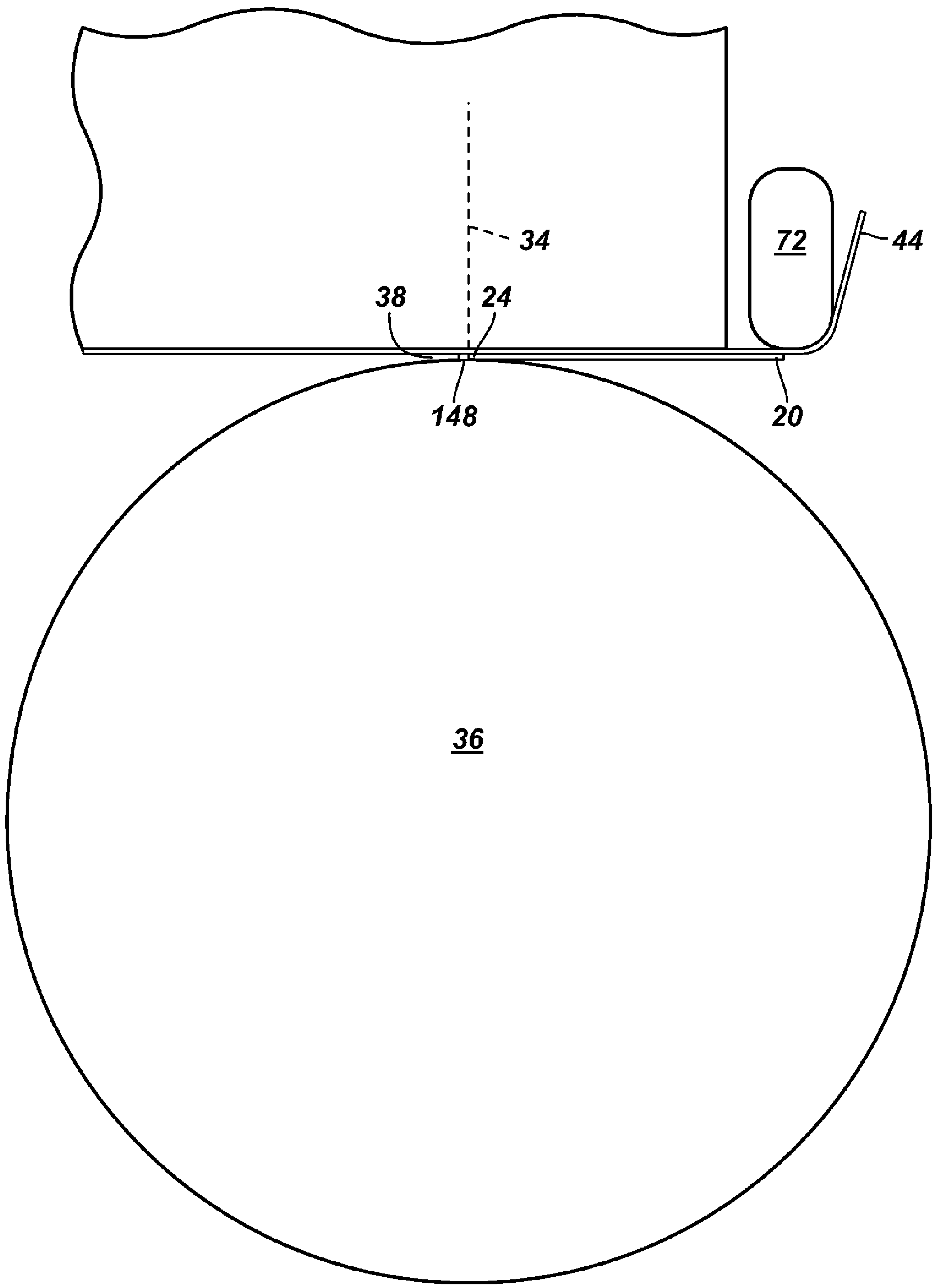


FIG. 7B

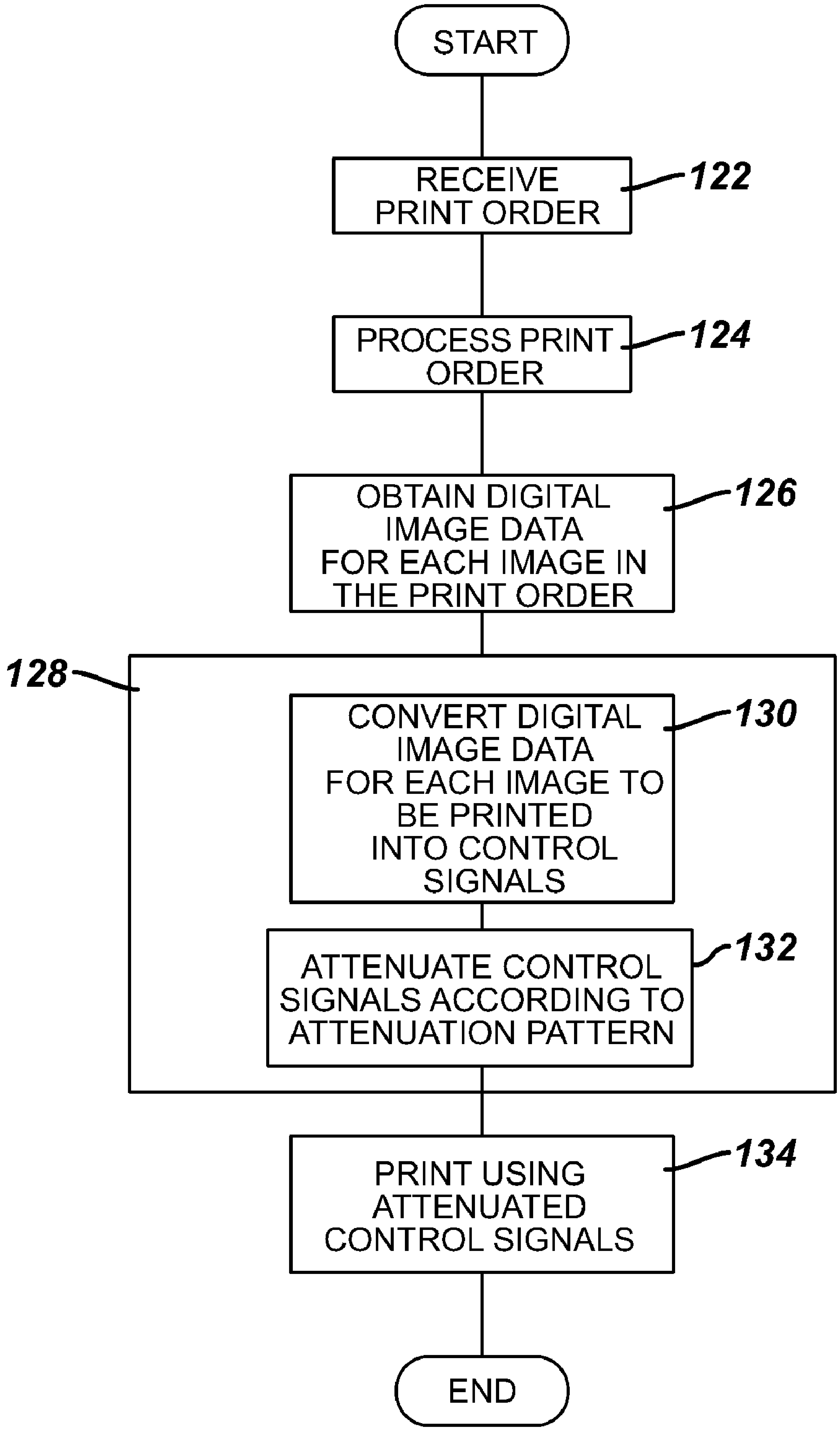

START
RECEIVE PRINT ORDER
122
PROCESS PRINT ORDER
124
OBTAIN DIGITAL IMAGE DATA FOR EACH IMAGE IN THE PRINT ORDER
126
128
CONVERT DIGITAL IMAGE DATA FOR EACH IMAGE TO BE PRINTED INTO CONTROL SIGNALS
130
ATTENUATE CONTROL SIGNALS ACCORDING TO ATTENUATION PATTERN
132
PRINT USING ATTENUATED CONTROL SIGNALS
134
END

FIG. 8A

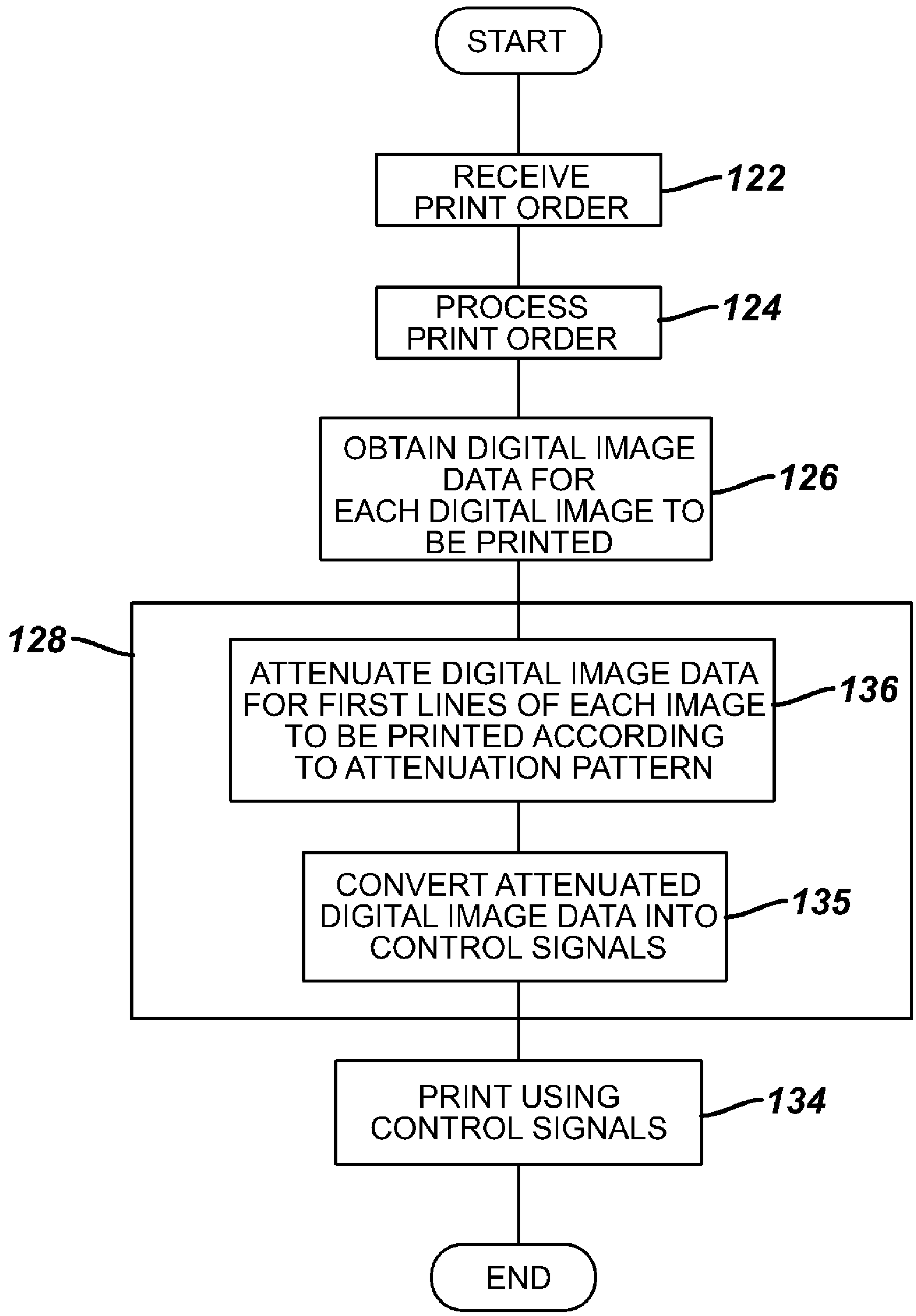

START
RECEIVE PRINT ORDER
122
PROCESS PRINT ORDER
124
OBTAIN DIGITAL IMAGE DATA FOR EACH DIGITAL IMAGE TO BE PRINTED
126
128
ATTENUATE DIGITAL IMAGE DATA FOR FIRST LINES OF EACH IMAGE TO BE PRINTED ACCORDING TO ATTENUATION PATTERN
136
CONVERT ATTENUATED DIGITAL IMAGE DATA INTO CONTROL SIGNALS
135
PRINT USING CONTROL SIGNALS
134
END

FIG. 8B

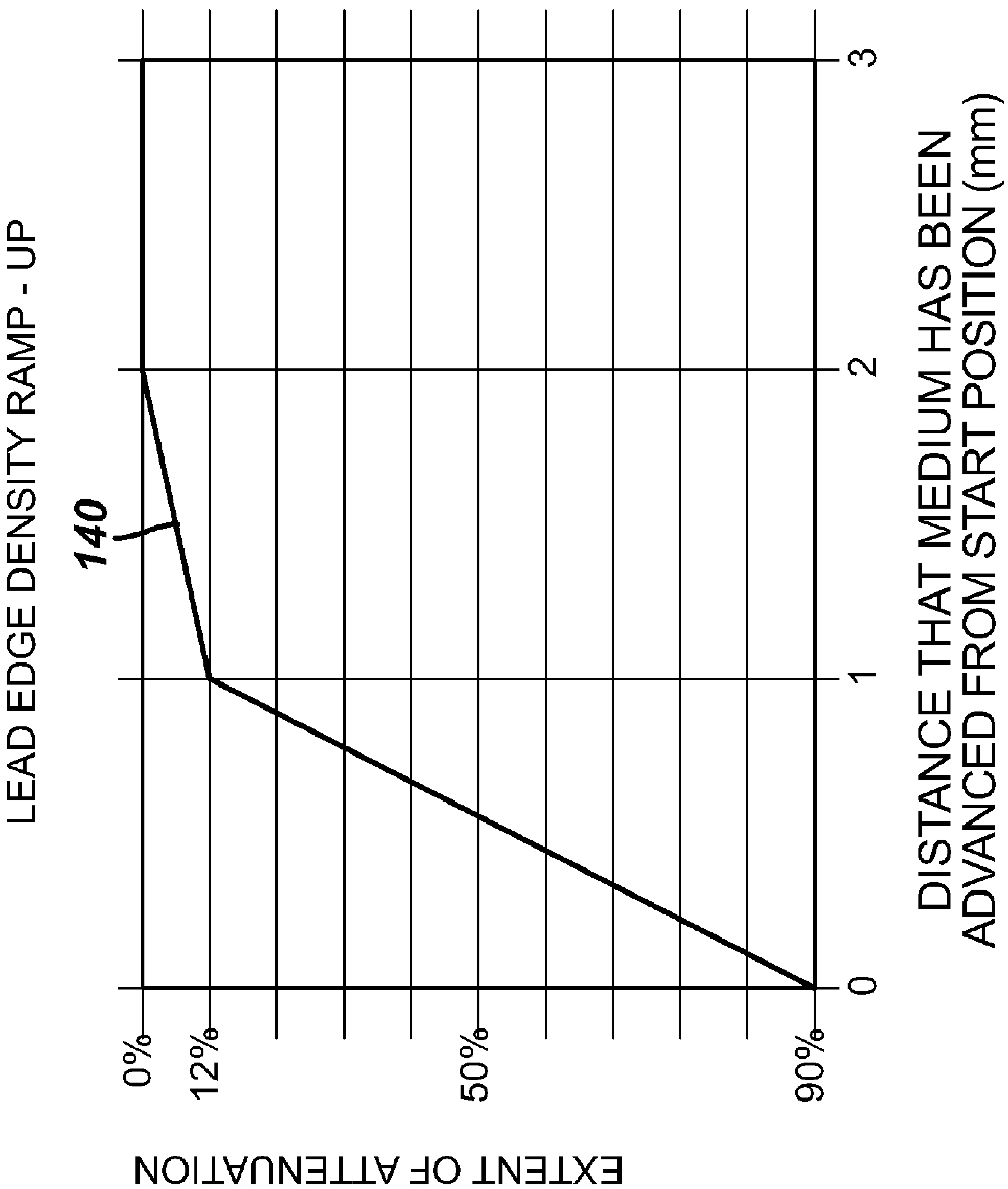

LEAD EDGE DENSITY RAMP - UP
140
EXTENT OF ATTENUATION
0%
12%
50%
90%
0
1
2
3
DISTANCE THAT MEDIUM HAS BEEN
ADVANCED FROM START POSITION (mm)

FIG. 9

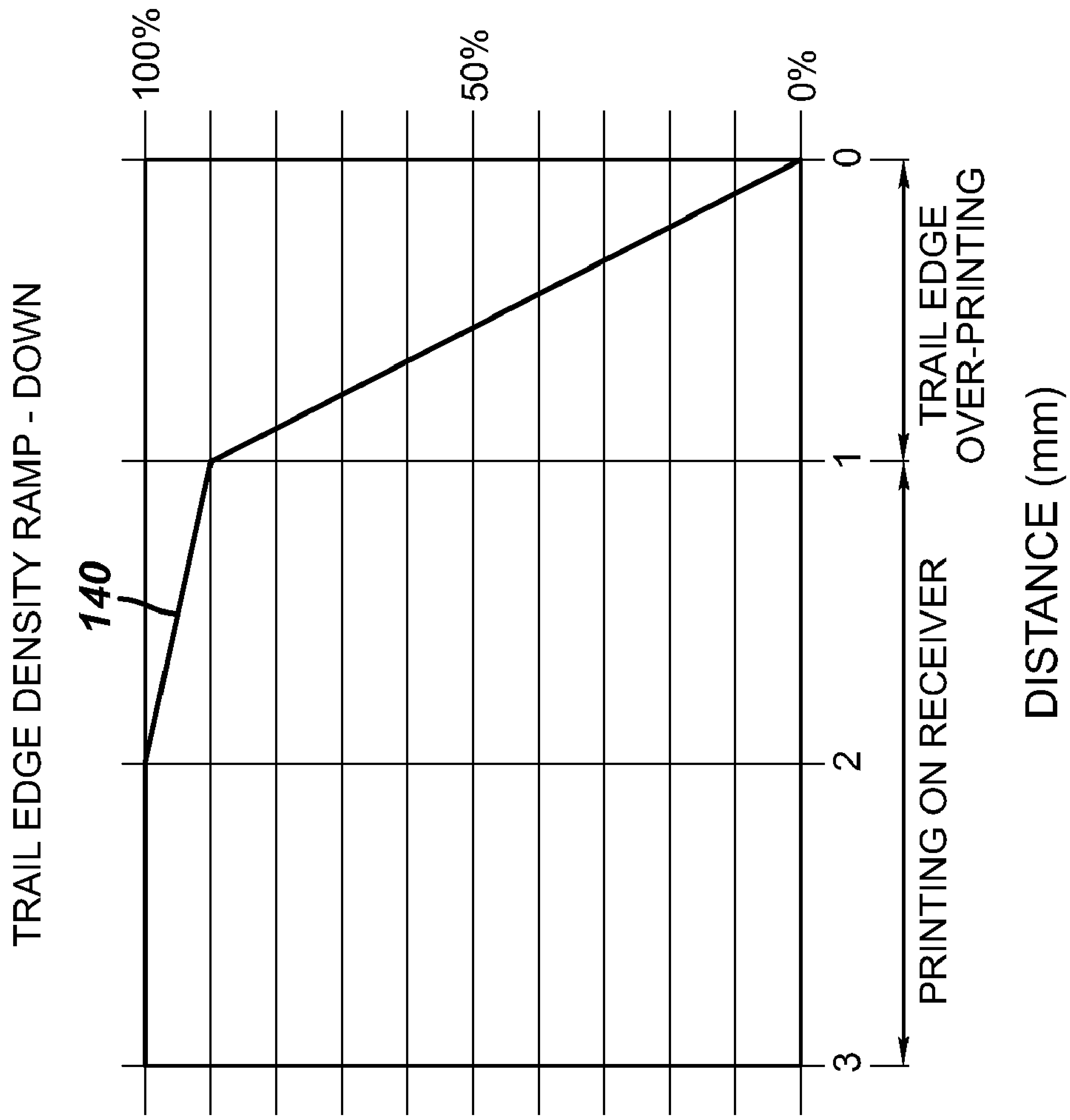

TRAIL EDGE DENSITY RAMP - DOWN
100%
50%
0%
140
0
1
2
3
TRAIL EDGE OVER-PRINTING
PRINTING ON RECEIVER
DISTANCE (mm)

FIG. 10

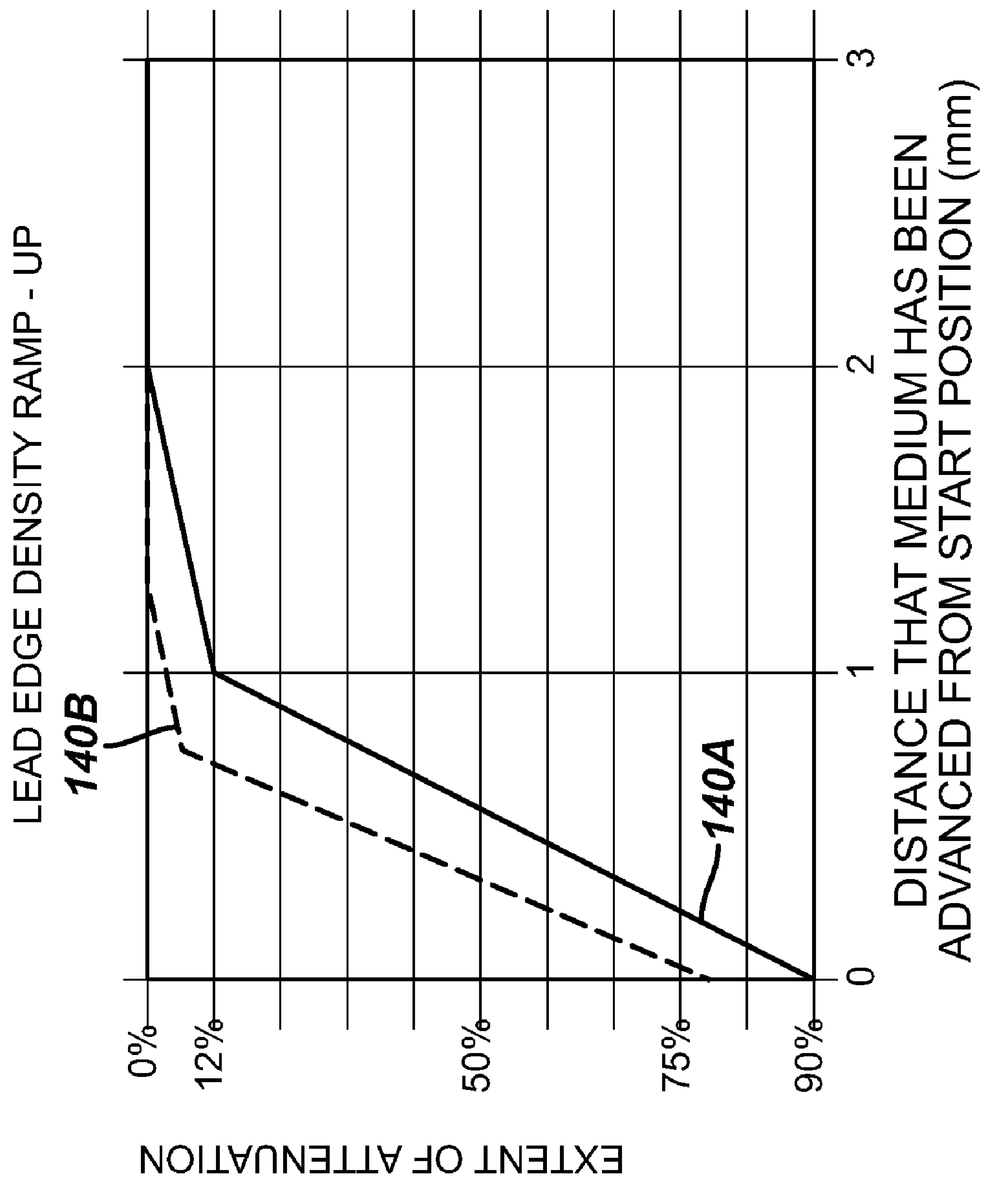

LEAD EDGE DENSITY RAMP - UP
140B
140A
EXTENT OF ATTENUATION
0%
12%
50%
75%
90%
0
1
2
3
DISTANCE THAT MEDIUM HAS BEEN
ADVANCED FROM START POSITION (mm)

FIG. 11

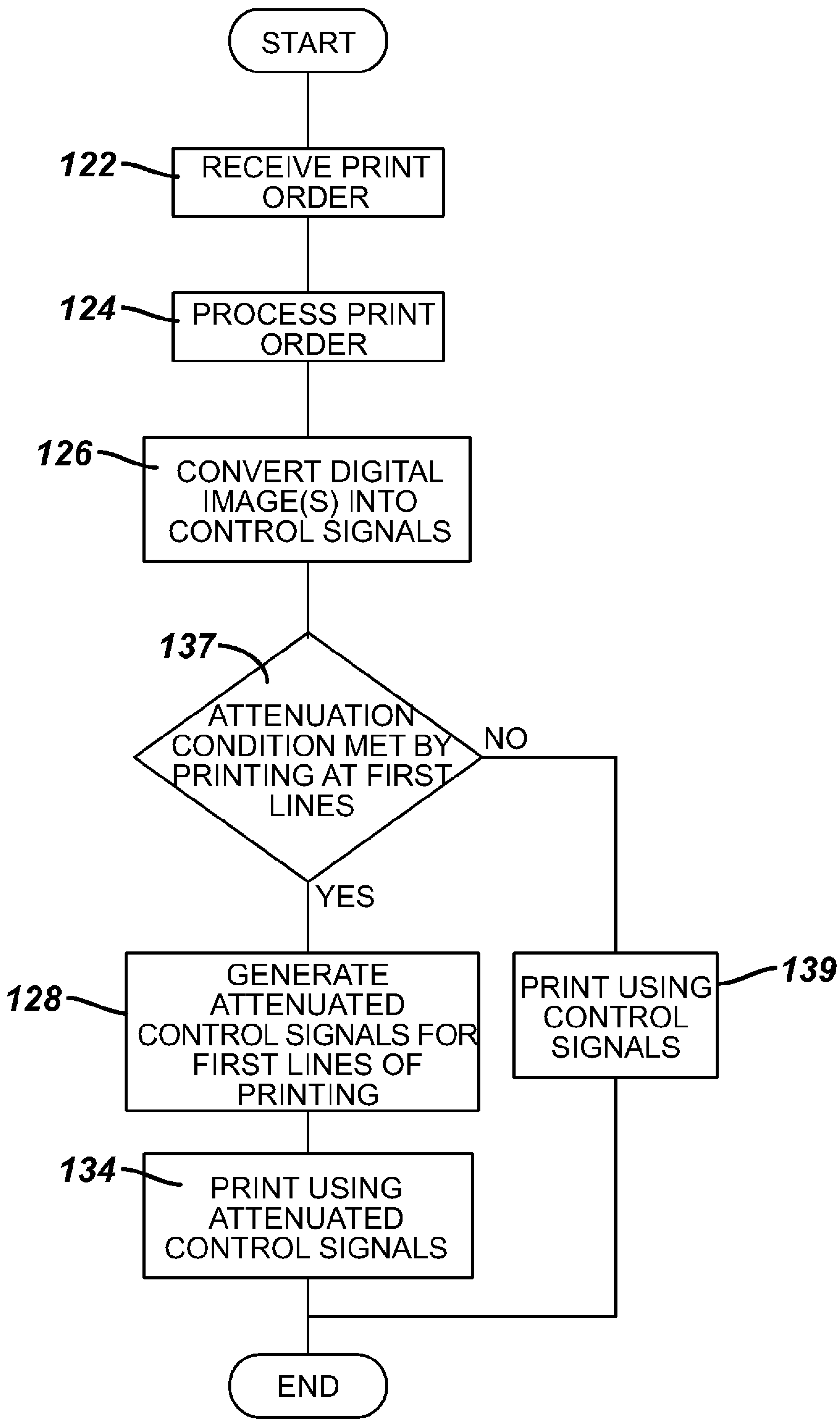

START
122
RECEIVE PRINT ORDER
124
PROCESS PRINT ORDER
126
CONVERT DIGITAL IMAGE(S) INTO CONTROL SIGNALS
137
ATTENUATION CONDITION MET BY PRINTING AT FIRST LINES
NO
YES
128
GENERATE ATTENUATED CONTROL SIGNALS FOR FIRST LINES OF PRINTING
139
PRINT USING CONTROL SIGNALS
134
PRINT USING ATTENUATED CONTROL SIGNALS
END

FIG. 12

THERMAL PRINTER WITH REDUCED DONOR ADHESION

CROSS REFERENCE TO RELATED APPLICATION

This is a Divisional of application Ser. No. 11/747,821 filed May 11, 2007 now U.S. Pat. No. 7,868,906, now allowed, which is hereby incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

This invention relates in general to methods of printing and printers and in particular to methods of borderless printing and printers for providing borderless prints.

BACKGROUND OF THE INVENTION

Many photographers use digital cameras to capture images. Unlike conventional wet processing of silver halide film and papers, digital images can be printed directly onto sheets of paper. Color images can be printed using ink jet printers, multicolor transferable toner printers, heat sensitive coated paper printers, or thermal dye transfer printers. Many mass-market retail establishments have user-friendly kiosks where shoppers can make color prints. A large number of these kiosks use thermal dye transfer printers. Because the kiosks use large amounts of paper, such kiosks often use a continuous web of paper for printing such images. The images are later separated from each other and from the web by a suitable cutter or knife. In such kiosk printers, the cutting process is typically performed in a manner that ensures that the printed images provided to the user have dye images extend to the edges of the print in both the latitudinal and longitudinal directions. These prints are known as borderless prints and are the most popular prints.

Thermal dye transfer printers generate very high quality images. As such, a number of photographers want their own thermal dye transfer printer. However, it is impractical and not cost effective to supply continuous web paper for use in home printing. It is also expensive to supply built-in paper cutters and knives to provide borderless prints. To attempt to meet the demand for borderless prints, there are known methods of extending the latitudinal edges so that there is no border on the tops and bottoms of prints. See, for example, U.S. Pat. Nos. 5,441,353; 5,196,863; and 5,499,880. However, those techniques cannot provide prints that extend to the longitudinal borders.

One approach to providing borderless prints in a sheet fed thermal printer is modeled after the technique used by home printers. In this approach receiver sheets are provided that are pre-perforated at a distance from each longitudinal edge. FIG. **1** shows a prior art thermal dye transfer printer **2** that is intended to provide monotone, multi-tone or full color borderless printing using a perforated sheet **4** is shown in FIG. **1**. Printer **2** records images on a sheet **4** that is driven along a print path by a pair of pinch rollers **6***a* and **6***b* connected to a motor **7**. A print head **8** is located opposite a free spinning platen **10** through which sheet **4** is passed during printing. Donor take-up roller **12** and donor supply roller **14** support a donor web **16** of thermal dye donor material and are positioned on opposite sides of print head **8** so that donor web **16** passes between print head **8** and platen **10**. A bias spring **18** presses print head **8** against donor web **16** to urge donor web **16** against platen **10**.

Prior to printing, a leading edge **4.1** of sheet **4** is fed between rollers **6***a* and **6***b*. Rollers **6***a* and **6***b* pull sheet **4** and donor web **16** between thermal print head **8** and platen **10** where thermal print head **8** causes donor material to be transferred to sheet **4**.

Sheet **4** is perforated to provide a separable perforated leading portion **4.1** and a trailing portion **4.3** bordering a central portion **4.2**. Donor material, such as a dye, is transferred to sheet **4** such that an image is formed that causes the entire central portion **4.2** and that optionally extends to leading portion **4.1** and trailing portion **4.3** slightly beyond the perforations. When leading portion **4.1** and trailing portion **4.3** are removed at the perforations, central portion **4.2** bears a printed image that extends from edge to edge, and the print appears to be borderless.

A key drawback of this solution is the requirement for special paper with perforations on the leading and trailing edges. Such paper is expensive to manufacture and has little or no other market outside of printing digital images. In addition, customers can be dissatisfied with the requirement of tearing off the perforated edges of the printed images.

Another approach to providing borderless sheet fed prints is to provide a thermal printer with systems that precisely detect the leading edge of a sheet **4** and that precisely positions a leading edge of a sheet at a print head. However, it will be understood that print lines in thermal printers can be arranged on the order of 300 or more lines per longitudinal inch of a sheet. It also will be understood that even a minor border on the order one print line will not be acceptable as a borderless print. This requires that the sensing and positioning equipment in the thermal printer be very precise, thus raising the cost of the printer.

Further, it will be understood that even minor variations in a length of sheet **4**, in the sheet transport systems used to position sheet **4** for printing, or in the equipment used to sense the position of sheet **4** can allow for a portion of sheet **4** to be advanced past print head **8** such that a border will appear. Such variations can also cause the leading longitudinal edge to be positioned before the print head such that the printer will begin printing before the longitudinal edge is positioned to receive the print. When this occurs, the leading edge longitudinal edge will appear to be borderless, however, because the printer begins printing without the leading edge at the print head and because the printer will print a predefined length, this problem creates a risk that the printer will stop printing before the trailing edge of the sheet has reached the print head thus creating a border at a trailing edge.

What is needed therefore is a printer and a method for printing that can achieve borderless printing without requiring the use of tear off receiver medium and/or slitting without precision sensing and positioning, and without a border. Such a system should be inexpensive and highly reliable.

SUMMARY OF THE INVENTION

Thermal printers and methods for operating a thermal printer having a thermal print head with an array of thermal elements position opposite a platen at a printing nip and with a donor web having thermal donor material positioned between the print head and the platen. The thermal elements are adapted to heat the donor web in accordance with received control signals so that donor material can be transferred from the donor web to the receiver medium. In accordance with the method a leading edge of the receiver medium is moved proximate to the printing nip. A sequence of thermal print head control signals is generated that is adapted to cause the array of thermal elements that causes the donor material to transfer from the donor web in a manner that is modulated in accordance with the image data and attenuated in accordance with an attenuation pattern. The leading edge of the receiver medium is urged through the printing nip while the thermal printhead control signals are transmitted to the thermal print head to cause the donor material to transfer from the donor web in an image modulated pattern having a longitudinal length that is larger than a longitudinal length of the receiver medium. The attenuation pattern provides a relatively high level of attenuation at a portion of the printing wherein there is a greater risk that the receiver medium will not be within the printing nip than at a portion of the printing wherein there is a lesser risk that the receiver medium will not be within the printing nip.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a mechanical schematic view of a prior art printer;

FIG. **2** is a mechanical schematic view of one embodiment of a printer;

FIGS. **3**A and **3**B are, respectively, schematic views of the apparatus with the receiver medium aligned to a sensor and an enlarged partial view of the receiver medium and the sensor;

FIGS. **4**A and **4**B are, respectively, views of the next step where the receiver medium is driven to an initial position proximate the heat/print line or the print head including an enlarged partial view of the initial position;

FIGS. **5**A and **5**B are views of the next step where the print head has moved vertically to clamp the receiver medium between the donor web and the platen with FIG. **4**B showing a detail of that clamping operation;

FIG. **6** shows a step of the process where the receiver medium is ejected from the apparatus;

FIGS. **7**A and **7**B illustrate a leading web and a trailing web formed by donor adhesion;

FIGS. **8**A and **8**B illustrate one method for operating borderless thermal printer to achieve borderless printing on a receiver medium with reduced possibility of donor adhesion problems;

FIG. **9** shows one embodiment of an attenuation pattern;

FIG. **10** shows another embodiment of an attenuation pattern;

FIG. **11** shows another embodiment of an attenuation pattern; and

FIG. **12** shows another embodiment of a method for operating a thermal printer to achieve borderless printing with reduced possibility of donor adhesion problems.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. **2-6** illustrate one embodiment of a borderless thermal printer **30**, FIGS. **7**A and **7**B illustrate a leading web and a trailing web formed by donor adhesion, and FIGS. **8**A and **8**B illustrate one method for operating borderless thermal printer **30** to achieve borderless printing on a receiver medium **20** with reduced possibility of donor adhesion problems. In the embodiment illustrated, borderless thermal printer **30** has a thermal print head **32** with an array of thermal elements **34** positioned opposite a platen **36** at a printing nip **38**. Platen **36** is coupled to a platen stepper motor **40** by a suitable transmission **41** such as a belt. Those skilled in the art understand that FIGS. **2-6** are schematic in nature and other suitable structure are possible for connecting platen stepper motor **40** to platen **36** in order to turn platen **36**. Such other structures include and are not limited to gear trains, and transmissions. A control circuit **42** sends suitable signals to control the

operation of platen stepper motor **40** in a manner that will be described in greater detail below.

The array of thermal elements **34** is adapted to heat a donor web **44** in accordance with control signals received from control circuit **42** and to heat in response thereto so that thermally transferable donor material can be transferred from donor web **44** to receiver medium **20**.

Donor web **44** is supplied by a donor supply roller **46** on one side of the thermal print head **32** and collected by a donor take-up roller **48** on an opposite side of thermal print head **32**. As will be discussed in greater detail below, during printing, donor web **44** travels across the array of thermal elements **34** and is wound on a donor take-up roller **48**. Donor web **44** carries thermally transferable donor material such as dyes, colorants, protective coating and/or metallic or other materials. Donor web **44** can comprise a single color of thermally transferable donor material for monotone printing, but it preferably comprises at least three sequential sections of differently colored thermally transferable donor material in order to provide full-color print and a clear section for applying a protective cover on the print. In a conventional fashion, thermal printer **30** has a bias spring **53** that urges thermal print head **32** toward platen **36**.

As is shown in FIG. **2**, borderless thermal printer **30** has a receiver medium advance system **50** that is adapted to move a leading edge **22** of receiver medium **20** between a loading position, for example, in receiver supply **23** and a print start position. In the embodiment of FIGS. **2-6**, receiver medium advance system **50** comprises a pick roller **52**, surface guides **54**, **56**, entrance urge rollers **58**, **60**, urge stepper motor **62**, transmission **64**, and print head guide **65**.

Entrance urge rollers **58**, **60** are disposed at one end of surface guides **54**, **56**. Entrance urge rollers **58**, **60** are biased together by a suitable spring or other biasing structure, not shown, so that rotary motion imported to one roller is transmitted to the other. Entrance urge roller **58** is a pinch roller and entrance urge roller **60** is driven by an urge stepper motor **62** and a transmission **64**. Transmission **64** is shown as a belt but may be any suitable transmission known in the art that can be used to connect the rotary motion of stepper motor **62** to entrance urge roller **60** including, but not limited to, a gear train or transmission. In operation, receiver medium **20** is advanced by urge rollers **58** and **60** through a nip between urge rollers **58**, **60** and is then supported by print head guide **65**. Print head guide **65** directs leading edge **22** to printing nip **38** as urge rollers **58** and **60** of receiver medium advance system **50** continue to advance receiver medium **20**. Entrance urge rollers **58**, **60** can be permanently engaged or can be selectively engaged. To selectively engage entrance urge rollers **58**, **60**, an entrance urge roller **58** can be spring biased away from urge roller **60** and an actuator (not shown) controlled by control circuit **42** is operable to move urge roller **58** or entrance urge roller **60** into or out of engagement with each other.

As is shown in FIGS. **3**A and **3**B, an edge sensor **70** is positioned relative to print head guide **65**. Edge sensor **70** can be, without limitation, an optical, mechanical, electromechanical, electromagnetic or a combination of optical, mechanical, electromechanical or electromagnetic device that at least senses receiver medium **20**. Edge sensor **70** is coupled to control circuit **42** and generates a sensor signal from which control circuit **42** can determine when leading edge **22** and, optionally, trailing edge **24** of receiver medium **20** are advanced through an area sensed by edge sensor **70**. Any conventional edge sensor **70** can be used including a wide variety of sensors that are well-known in the printing and photocopying art. In addition, edge sensor **70** may be combined with a suitable gate (not shown) or other signal modifying, amplifying or attenuating circuits so the sensor signal is provided to control circuit **42** in a manner that is readily usable thereby. Those skilled in the art understand that in this embodiment receiver medium **20** has its lateral sides aligned and deskewed so that leading edge **22** of receiver medium **20** is transverse to a path **43** of travel and is substantially aligned parallel to the linear array **34**.

As is shown in FIGS. **4**A and **4**B, when edge sensor **70** generates a signal indicating that leading edge **22** of receiver medium **20** has been detected, control circuit **42** drives urge stepper motor **62** a predetermined number of steps. This causes urge rollers **58**, **60** to drive receiver medium **20** toward array of thermal elements **34** and to stop receiver medium **20** with its leading edge **22** at an initial position that is a distance D from the array of thermal elements **34**. The initial position is close enough to array of thermal elements **34** so that leading edge **22** of receiver medium **20** will be captured between thermal print head **32** and platen **36**. In FIG. **4**B, leading edge **22** of receiver medium **20** is shown at location D that is approximately 0.020 inches (0.0368 cm) from the array of thermal elements **34**, however, the separation can be greater or lesser as desired.

After receiver medium **20** is in the initial position, control circuit **42** causes a motor (not shown) to drive thermal print head **32** downward in the direction of arrow **53** in order to clamp receiver medium **20** and donor web **44**, between thermal print head **32** and platen **36**, as is shown in FIGS. **5**A and **5**B. With receiver medium **20** in the initial position, control circuit **42** actuates platen stepper motor **40** such that receiver medium **20** and donor web **44** driven past array of thermal elements **34**, while array of thermal elements **34** are energized in an imagewise fashion so as to transfer thermally transferable donor material from donor web **44** to receiver medium **20** to record an image on receiver medium **20**.

As shown in FIG. **6**, after receiver medium **20** passes array **34**, a peel plate **72** sharply alters the direction of donor web **44** relative to receiver medium **20** to separate donor web **44** from receiver medium **20** as receiver medium **20** continues to travel in generally the same direction or until it is redirected in another direction. In one embodiment, receiver medium **20** can continue such travel along an exit path that causes receiver medium **20** to pass out of printer **30** as a completed printed image.

In the embodiment illustrated, receiver medium **20** passes into a receiver medium return system **80** after donor web **44** is separated from receiver medium **20**. Receiver medium return system **80** comprises an arrangement of guides, gates, rollers or other structures that is responsive to control circuit **42** and that can direct receiver medium **20** along a return path **82** that returns receiver medium **20** to a position that allows receiver medium advance system **50** to reload receiver medium **20** so that additional images can be printed thereon or to an exit path **84**.

As shown in the embodiment of FIGS. **2-6**, receiver medium return system **80** comprises exit guides **86**, **88** which lead receiver medium **20** from printing nip **38** and into the nip of exit urge rollers **90** and **92**. Exit urge rollers **90** and **92** are likewise driven to rotate by an actuator (not shown) that is under control of control circuit **42**. Exit urge rollers **90** and **92** are operable to rewind and feed receiver medium **20** back toward urge rollers **58**, **60**. This can be done to rewind receiver medium **20** so that it is reloaded for a second printing, for example, to enable multicolor printing and/or laminating. In other embodiments, a return system **80** can provide a recirculating type return path (not shown) that guides leading edge **22** from exit urge rollers **90**, **92** to entrance urge rollers **58**, **60** without passing receiver medium **20** through printing nip **38**. A wide variety of recirculating return paths of this type are known in the printing, scanning, and photocopying arts. Examples of such recirculating return paths are illustrated in, for example, co-pending U.S. application Ser. No. 11/176,147 entitled "Printer with Multi-Pass Media Transport" filed by Cloutier et al. on Jul. 7, 2005; or U.S. Pat. No. 5,838,357 to Maslanka et al., issued Nov. 17, 1998, entitled "Thermal Printer Which Uses Platen to Transport Dye Donor Web Between Successive Printing Passes"; U.S. Pat. No. 5,798,783 to Maslanka et al., issued Aug. 25, 1998, entitled "Thermal Printer with Sensor for Leading Edge of Receiver Sheet"; U.S. Pat. No. 5,841,460 to Maslanka et al., issued Nov. 24, 1998, entitled "Thermal Printer which Recirculates Receiver Sheet Between Successive Printing Passes"; and U.S. Pat. No. 5,850,246 to Maslanka et al., issued Dec. 15, 1998, entitled "Thermal Printer with Improved Print Head Assembly". After printing is completed, control circuit **42** sends signals to an actuator (not shown) that cause exit urge rollers **90**, **92** discharge receiver medium **20** along an exit path **84** into a discharge bin **94**, as shown in FIG. **2**.

It will be appreciated that receiver medium advance system **50** provides relatively precise location of leading edge **22** of receiver medium **20** in that edge sensor **70** can sense leading edge **22** of receiver medium **20** with a great deal of accuracy and in that stepper motors can be used to precisely drive sets of exit urge rollers **90**, **92** and platen **36** to move receiver medium **20** by an initial amount from the detected position. In this way, thermal-dye transfer material may be transferred from leading edge **22** of receiver medium **20** to trailing edge **24** of receiver medium **20**. However, it will be understood that in other embodiments, any other conventional system known for positioning a receiver medium **20** proximate to an array of thermal elements **34** can be used.

It will also be appreciated, however, that even with the most precise placement of leading edge **22**, minor variations in the length of receiver medium **20**, the receiver medium advance system **50** used to position receiver medium **20** for printing, platen **36**, transmission **41** or platen stepper motor **40**, or in the equipment used to sense the position of the receiver medium can cause receiver medium **20** to be positioned at the start of printing such that multiple lines of thermal donor material will be printed before leading edge **22** of receiver medium **20** enters printing nip **38** between thermal elements **34** of thermal print head **32** and platen **36**, thus creating a risk of thermal adhesion of the thermally transferable donor material to platen **36**. As is conceptually illustrated in FIG. **7**A, this can cause a section of thermally transferable donor material to be transferred to platen **36** at the start of printing creating a leading edge web **138** of molten, semi-molten or form of donor transfer material between platen **36** and donor web **44** which either interferes with the movement of receiver medium **20** as it enters printing nip **38** by blocking movement of receiver medium **20** through printing nip **38** or creates unintended image artifacts in an image printed using receiver medium **20**. Similarly, the same factors can cause printing to continue after all of receive medium **20** has passed through printing nip **38**, forming a trailing web **148** between donor web **44** and platen **36**, which can create similar interference or image artifacts.

To avoid these outcomes a thermal printer **30** and method for operating a thermal printer **30** are provided that can reduce the possibility of thermal donor adhesion, such as might cause a leading edge web **138** to form while still providing borderless prints.

FIG. **8** illustrates one embodiment of a method for operating the borderless thermal printer **30** of FIGS. **2-6** to reduce the possibility of thermal donor adhesion. As is illustrated in FIG. **8**, the printing process begins when thermal printer **30** receives a print order from an interface **100** (step **122**). The print order provides instructions sufficient for control circuit **42** to begin a print sequence and can include an instruction to print an image, the image data for the image to be printed, print quantity information or information identifying a selected receiver medium **20** upon which the image is to be printed. The print order can also contain other information including but not limited to as delivery date, delivery destination information, consumer information, and point of sale information.

Interface **100** can incorporate any known circuits or systems that are capable of receiving a print order or data forming part of the print order. By way of example, and not limitation, in the embodiment illustrated in FIGS. **2-6**, interface **100** has a user input system **102**, a communication system **104**, and a memory reader **106** that can be used for obtaining information forming all or at least a part of a print order.

User input system **102** can comprise any form of transducer or other device capable of receiving an input from a user and converting this input into a form that can be used by control circuit **42**. For example, user input system **102** can comprise a touch screen input, a touch pad input, a 4-way switch, a 6-way switch, an 8-way switch, a stylus system, a trackball system, a joystick system, a voice recognition system, a gesture recognition system or other such systems. In the embodiment illustrated in FIG. **2**, user input system **102** includes a keypad **108** and mouse **110** for receiving input from a user. A display **112** is connected to control circuit **42** and provides information and feedback to the user to facilitate user input actions and for other purposes.

Communication system **104** is adapted to enable communications between thermal printer **30** and an external devices, networks and systems. Examples of such external devices include but are not limited to local, regional and international data and telecommunication networks, computers, databases, printers, cameras, cellular phones, personal digital assistants, internet appliances, the internet and any associated devices, televisions, assistive technology devices and any other communication, data or other devices that can be used to generate, process, edit, distribute or otherwise send or receive data that can be related to a print order or other function that is performed by thermal printer **30**.

Communication system **104** can be for example, an optical, radio frequency or transducer circuit or other system that converts image and other data into a form that can be conveyed to such external devices such as a remote memory system by way of an optical signal, radio frequency signal or other form of signal. Communication system **104** provides control circuit **42** with information and instructions from signals received thereby.

In the embodiment of FIGS. **2-6**, memory interface **118** comprises a memory card slot **114** that holds a removable memory **116** such as a removable flash card or other form of memory card or memory device and has a removable memory interface **118** for communicating with removable memory **116**. Data including but not limited to control programs, digital images and metadata can also be stored in a remote memory system. In other embodiments, removable memory **116** can take other forms such as, a removable optical, magnetic or other disk memory (not shown).

Each print order generally provides information from which control circuit **42** can determine what images are to be printed, how the images are to be printed and the quantity of each of the images that is to be printed. A print order can be associated with digital image data representing the image to be printed and instructions for printing such an image. However, other print orders can be associated with digital image data by providing reference information instead of digital image data with the reference information being useable by control circuit **42** to obtain digital image data from an external source such as by using communication system **104** or memory interface **118**. In some cases, the printing instructions can be provided in the form of digital print order format (DPOF) data that allows a user of a digital camera or other type of display device to define which of a set of stored images are to be printed, and can also provide information that identifies number of copies or other image information that can be used in fulfilling a print order.

Control circuit **42** processes the print order data to determine what images to print and in what manner. In this regard, control circuit **42** processes non-image data in the print order to determine factors such as quantity information, print type information, enlargement or reduction factors, collation information and the like (step **124**).

Control circuit **42** then obtains digital image data for each image in the print order (step **126**). As is noted above, such image data is typically transmitted with the print order data and can be obtained therefrom. In certain circumstances, the print order data provides information indicating how the digital image data can be obtained, such as by providing address and, optionally, access information, allowing such data to be downloaded from a removable memory **116** or from a source connected to borderless thermal printer **30** by way of communication system **104**.

Control circuit **42** then determines control signals that are adapted to cause thermal printer **30** to print borderless images on receiver medium **20**. To do this control circuit **42** generates control signals for array of thermal elements **34** that cause the array of thermal elements **34** to radiate heat as necessary to cause donor material to transfer from donor web **44** to receiver medium **20** to form a printed image on the receiver medium **20**. Typically, such control signals are based upon the image data for the image to be printed and any print order data indicating a print size, shape or orientation, and include control signals enabling the printing of an image having a longitudinal length that is longer than a longitudinal length of the receiver medium. For the purposes of the examples herein it will be assumed that the print order calls for a borderless printing of a single image.

As is noted above, to ensure that such borderless printing occurs, receiver medium **20** is positioned with a leading edge **22** separated from printing nip **38** by a distance D, thus allowing printing to begin just before leading edge **22** reaches nip, so that it is certain that leading edge **22** will receive donor material deposited in an imagewise fashion.

However, as is illustrated in FIG. **7**A, this creates a risk that donor material will be applied to platen **36** in a fashion that allows such donor material to adhere to platen **36** and create leading edge web **138** of molten and/or semi-molten donor material between platen **36** and donor web **44**. Where such a leading edge web **138** is formed from a substantial amount of donor material, web **138** can impede or block receiver medium **20** from passing through printing nip **38** or can create unwanted image artifacts. Accordingly, in the embodiments described a step of forming attenuated control signals (step **128**) comprises forming such signals in accordance with an attenuation pattern that reduces the amount of or density of thermal donor material to minimize the risk of forming a type of leading edge web **138** that can impede or block the transit of receiver medium **20** through printing nip **38**.

In the embodiment of FIG. **8**A, control circuit **42** performs step **128** by first converting the digital image data into control signals that can be used by thermal print head **32** (step **130**) and then attenuating the control signals according to an attenuation pattern (step **132**).

In this embodiment, this step of converting the digital image data into control signals (step **130**) involves converting the digital image data into printer code values or other data types that represent specific colors to be printed on receiver medium **20** to form an image. This is typically done in accordance with so-called calibration information that provides a logical association between the colors called for in the image data and printer code values that are assumed to cause such colors to be printed by thermal print head **32**. Such calibration information can also include information that printer **30** can use in determining printing actions to be taken in response to particular code values.

The calibration information can be predetermined using calibration data that is established during an initial set up phase at a manufacturer's facility or elsewhere. However, because many aspects of printing, particularly color printing, are influenced by environmental conditions, printing process variations, and donor and receiver material variations, it is understood that, from time to time, it may be useful to recalibrate the initial printer settings to ensure that the colors that are printed correspond to colors called for in the print data. Accordingly, the process of converting digital image data into code values can adapt to such conditions by recalibrating printer settings according to feedback from using sensors that monitor such conditions, feedback from sensors that monitor the colors printed in response to particular code values or using manual feedback systems.

During printing, the code values are converted into control signals which govern the extent to which thermal elements in array **34** are energized. The thermal elements of array **34** radiate heat in proportion to the extent to which they are energized and the thermal donor material transfers from donor web **44** in proportion to the amount of heat applied thereto. Accordingly, in a conventional thermal printer, an image is formed using the thermal donor materials by supplying control signals to the thermal print head **32** as the donor web **44** and receiver medium **20** are moved by the platen to advance the receiver sheet and the donor web past array of thermal elements **34**.

In the embodiment illustrated in FIG. **8**A, the control signals are generated on a line by line basis and, during printing, control circuit **42** transmits a first line of control signals, then control circuit **42** transmits signals to platen stepper motor **40** causing platen stepper motor **40** to rotate in a manner that advances platen **36** by a distance that is intended to position receiver medium **20** so that the array of thermal elements **34** can print a second print line. Control circuit **42** then sends a second line of control signals to array of thermal elements **34**. Printing continues in this manner until all print lines for the image have been printed.

However, in the embodiment of FIG. **8**A, before the image based control signals are used for printing, control circuit **42** attenuates the control signals to lower the density of the printing according to an attenuation pattern.

FIG. **9** illustrates one embodiment of this attenuation pattern **140**. In the attenuation pattern of FIG. **9**, the extent of attenuation indicated by attenuation pattern **140** is relatively high during a first few lines of printing and can be as high as 90% or more in during these lines, however, the extent of attenuation is decreased as additional steps are taken. This reflects, in a general way, the probability that leading edge **22** of receiver medium **20** will be positioned in printing nip. More specifically, it will be appreciated that, a borderless thermal printer **30** using receiver medium advance system **50** that anticipates positioning receiver medium **20** with a leading edge **22** separated from printing nip **38**, it is unlikely that leading edge **22** will be positioned at printing nip **38** when the first line of the image is printed. Thus, the attenuation is greatest at the first line of printing of the image and is reduced as printing continues.

However, with each step that platen stepper motor **40** causes platen **36** to take, it becomes more likely that leading edge **22** of receiver medium **20** will enter printing nip **38**. Accordingly, attenuation pattern **140** provides a density decreasing the extent of attenuation with the extent of urging supplied by platen **36** and platen stepper motor **40** until the extent of the attenuation reaches to a minimum level of attenuation, shown in FIG. **9** as a 0% level of attenuation. It will be appreciated that using such an approach ensures that even where some donor material is transferred onto platen **36** during the first line(s) of printing, the amount of donor material transferred will be minimized so that, if necessary, leading edge **22** can be thrust through leading edge web **138** by the action of platen **36** to avoid blockage and with minimal risk of unwanted image artifacts.

The attenuated control signals are then used for printing as generally described above (step **134**).

In the embodiment of FIG. **8**B, control circuit **42** performs step **128** by attenuating the digital image data for the image to be printed according to an attenuation pattern (step **136**) and then converts the attenuated digital image data into attenuated control signals that can be used by thermal print head **32** (step **138**). In this embodiment, the step of attenuating the digital image data comprises determining which portions of the digital image data represent portions of the image that will be printed during the first few lines of printing and adjusting the density of the colors called for in those lines according to the attenuation pattern. The attenuated image data is converted to create attenuated control signals in the same fashion that is used to convert any form of digital image data into control signals, such as the fashion described above with respect to step **130**.

It will also be appreciated that, in order to ensure that a digital image is printed at a trailing edge **24** of receiver medium **20**, it is useful to continue printing the image data such that it can be anticipated that printing of the image will continue so that all portions of receiver medium **20**, of any length or that is positioned within any range of positions relative to the initial position, will be printed. Thus, there exists a possibility that a trailing web **148** of donor material can be formed between platen **36** and donor web **44** under certain circumstances. This can interfere with the movement of subsequent receiver mediums through printing nip **38**. Accordingly, attenuation pattern **140** can provide for a trailing edge density ramp down, such as is illustrated in FIG. **10**, during which the control signals are attenuated in an increasing fashion to reach a relatively high level of attenuation as the printing of the image nears an end. This density ramp down can be initiated when control circuit **42** receives signals from edge sensor **70** indicating that trailing edge **24** has passed edge sensor **70** or at some predetermined number of steps of movement of receiver medium **20** after trailing edge **24** has passed edge sensor **70**.

Here too, attenuation pattern **140** is generally based upon the probability that a particular line will be printed with no receiver medium **20** positioned at printing nip **38**. As this probability increases, the extent of the density ramp down is increased. Printing is then performed using the attenuated control signals (step **132**).

The attenuation patterns, illustrated in FIGS. **9** and **10**, are exemplary only and a wide variety of other attenuation patterns may be used. A variety of factors can be used to determine an attenuation pattern for a material.

For example, and without limitation, it will be appreciated that different types of donor material may exhibit different tendencies to form a leading edge web **138** or a trailing web **148**. Donor material that has a tendency to deposit more material per level of heat applied may have a propensity to form a leading edge web **138** or a trailing web **148** at lower temperatures than a donor material that has a tendency to deposit less material per level of heat applied. For example, in color printing where donor web **44** carries a plurality of different types of differently colored donor material, a darker color may comprise donor material that is denser or that applies more donor material than a lighter colored material. Similarly, donor material that has metals in it may be denser than donor material that does not have metals in it. In such cases, an attenuation pattern **140***a*, such as the one illustrated in FIG. **11**, can be used for the donor material that deposits more material per level of heat applied, while a different attenuation, pattern **140***b*, is used for donor materials that deposit less donor material per unit area. As can be seen, attenuation pattern **140***a* provides a greater extent of attenuation as well as a more gradual rate of attenuation ramp down.

It will be appreciated that other factors related to donor material type can also have a similar influence, such as a known viscosity or cooling rate of the donor material, inherent adhesive properties if any of the donor material, the type of material used to support donor material on donor web **44**, or any other known materials or properties of donor web **44** or the donor material thereon. Properties of platen **36**, such as cooling rate, adhesion characteristics, the shape and size of platen **36**, and other factors, may also influence the attenuation pattern.

Further, it will be appreciated that during printing different environmental conditions can increase probability of forming a leading edge web **138** or trailing web **148** that impede or block the transit of receiver medium **20**. For example, when platen **36** is colder, donor material can cool faster and is more likely to adhere to platen **36** in a manner that creates problems. In contrast, when platen **36** is warmer there is less likelihood of such adhesion, accordingly as shown in FIG. **12**, where it is determined that platen **36** is or should be warm such as where a temperature sensor (not shown) indicates that platen **36** is warm or when there have been a significant number of printed images within a period of time to warm platen **36**, attenuation patterns **140***a* and **140***b* can be adjusted, to allow for lesser or greater attenuation based upon such factors.

FIG. **12** shows the embodiment of FIG. **8**A, with the generating step **128** further comprising optional additional steps of determining whether an attenuation condition is met, suggesting that an attenuation pattern should be used. In one example, it is determined that the attenuation condition is met when leading (or trailing) edge of the image to be recorded on receiver medium **20** has image elements that require high density printing (step **137**). Typically, this determination_can be made by analyzing the density of the colors identified in the digital image data for the leading edge or trailing edge of an image to be printed, by analyzing code values derived from the digital image data, or by analyzing control signals generated for such areas. As noted above, during the printing in these areas there is a higher risk that at least some printing will occur with no receiver medium **20** present between the array of thermal elements **34** of thermal print head **32**.

The purpose of this analysis is to identify when the printing of an image may occasion the delivery of sufficient amounts of thermal donor material proximate to a leading or trailing edge of the image to create a risk of the formation of a leading edge web **138** or trailing web **148**. This analysis can be performed by totaling the digital image data, code values, or control signals, by calculating an average, for regions of the image proximate to a longitudinal edge. Where this is done a threshold is set as a total above which it is determined that attenuation is to be performed and below which no attenuation is performed. Similarly, statistical means, or other statistical analysis of the digital image data, code values, or control signals can be performed with the outcome thereof compared to a threshold.

Alternatively, this can be done by comparing a pattern of threshold values to a pattern of digital image data, code values or control signals representing areas proximate to an edge of receiver medium **20**, such as areas that are printed at a beginning portion of the image or as the printing of the image nears an end. It will be appreciated that any other know statistical, mathematical, neural or other form of analysis can be used in order to analyze the digital image data, code values or control signals for portions of the image that are proximate to an edge of the image to be printed and to characterize the amount of donor material that will be conveyed to print such portions such that a determination can be made as to whether an attenuation condition is met. Such a determination can be made for each donor patch, or for the printed images as a whole. Such a determination can be made based upon image data, code values or control signals for portions of the image to be printed that are proximate to a leading edge of the image, proximate to a trailing edge of the image to be printed or both.

As is noted above, printing conditions may influence the potential for a leading edge web **138** or a trailing web **148** to form. Such printing conditions can be used to adjust a threshold used in the determining step (step **137**), or to adjust the analysis performed during the determining step (step **137**). For example, for some printers and donor material, where the temperature of the printer is higher then the threshold can be lowered in that there is a lesser chance of donor material adhering to platen **36** at such higher temperatures.

Where it is determined that no such high density printing condition is called for (step **137**) the attenuation pattern is not applied to the control signals and the control signals (step **139**) are used for printing (step **134**). Where it is determined that such a high density printing condition is called for the steps of generating attenuated control signals (step **128**) and printing using the attenuated control signals (step **134**) can be performed.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

PARTS LIST

4	sheet
4.1	leader portion or leading edge
4.2	central portion
4.3	trailing portion
6a	pinch roller
6b	pinch roller
7	motor
8	print head
10	platen
12	donor roller
14	supply roller
16	donor web

-continued

18	bias spring
20	receiver medium
22	leading edge of receiver
23	receiver supply
24	trailing edge of receiver
30	thermal printer
32	thermal print head
34	linear array of thermal elements
36	platen
38	printing nip
40	stepper motor
41	transmission
42	control circuit
43	path of travel
44	donor web
46	donor supply roller
48	donor take-up roller
50	receiver medium advance system
52	pick roller
53	bias spring
54	surface guide
56	surface guide
58	entrance urge roller
60	entrance urge roller
62	urge stepper motor
64	transmission
65	print head guide
70	edge sensor
72	peel plate
80	receiver medium return system
82	return path
84	exit path
86	exit guides
88	exit guides
90	exit urge roller
92	exit urge roller
94	discharge bin
100	interface
102	user input system
104	communication system
106	memory reader
108	keypad
110	mouse
112	display
114	memory card slot
116	memory
118	memory interface
122	receive print order step
124	process print order step
126	obtain image data step
128	form attenuated control signals step
130	convert image data into control signals step
132	attenuate control signals step
134	print using control signals step
135	convert attenuate digital data into control signals step
136	attenuate digital image data step
137	determine high density printing step
138	leading edge web
139	print using control signals step
140	attenuation pattern
140a	attenuation pattern
140b	attenuation pattern
142	attenuation pattern
148	trailing web

The invention claimed is:

1. A thermal printer comprising:

a thermal print head having an array of thermal elements positioned opposite a platen at a printing nip with a donor web having thermal donor material positioned between the print head and the platen, said thermal elements being adapted to heat the donor web in a manner that is modulated in accordance with received control signals so that donor material can be transferred from the donor web to a receiver medium;

a receiver medium advance system adapted to advance a leading edge of the receiver medium proximate to the printing nip; and

a controller adapted to receive image data and to convert the image data into a sequence of thermal print head control signals adapted to cause the array of thermal elements to heat in a manner that causes the donor material to transfer from the donor ribbon in accordance with image data and attenuated in accordance with an attenuation pattern;

said controller being operable to print the image in the image data by causing the receiver medium advance system to urge the leading edge of the receiver medium through the printing nip while transmitting the thermal print head control signals to the thermal print head to cause the donor material to transfer from the donor web in an image modulated pattern having a longitudinal length that is larger than a longitudinal length of the receiver medium;

wherein said attenuation pattern provides a level of attenuation at a first portion of a printing that is higher than a level of attenuation at a second portion of the printing.

2. The printer of claim 1, wherein said first portion of the printing is at a beginning portion of the printing and the level of attenuation is reduced as the printing progresses.

3. The printer of claim 1, wherein said attenuation pattern increases the level of attenuation as the printing nears an end.

4. The printer of claim 1, wherein the extent of the attenuation is further determined based upon the properties of the thermal donor material being transferred during the printing.

5. The printer of claim 1, wherein the extent of the attenuation is further determined based upon the size, shape, temperature or adhesive characteristics of the platen.

6. The printer of claim 1, wherein the extent of the attenuation is determined based upon the image content proximate to a leading edge of the image such that higher attenuation is used when the image density of the image content is proximate to a leading or trailing edge of the image.

7. A thermal printer comprising:

a thermal print head having an array thermal elements positioned opposite a platen at a printing nip with a donor web having thermal donor material positioned between the print head and the platen, said thermal elements being adapted to heat a donor web in accordance with received control signals so that donor material can be transferred from the donor web to a receiver medium;

a means for moving a leading edge of the receiver medium proximate to the printing nip;

a means for generating a sequence of thermal print head control signals adapted to cause the array of thermal elements to heat in a manner that causes the donor material to transfer from the donor web in a manner that is modulated in accordance with image data and attenuated in accordance with an attenuation pattern; and

a means for urging the leading edge of the receiver medium through the printing nip while transmitting the thermal print head control signals to the thermal print head to cause the donor material to transfer from the donor web in an image modulated pattern having a longitudinal length that is larger than a longitudinal length of the receiver medium;

wherein said attenuation pattern provides a level of attenuation at a first portion of a printing that is higher than a level of attenuation at a second portion of the printing.

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